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GIRI INSTITUTE OF DEVELOPMENT STUDIES, LUCKNOW

Workshop on

Productivity and Equity in Irrigation System

(September 21-23, 1982)

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Seminar

September 21-23 1982

Contents

WORKSHOP ON PRODUCTIVITY AND EQUITY IN IRRIGATION SYSTEMS IN INDIA

Implementation of the government policy concerning productivity and equity in India is handicapped by three fold reasons. First, the area is marked by the paucity of research and the little research that has been done in this field is of isolated nature. The researchers with engineering background have confined themselves to the analysis of technical aspects while the social scientists have not gone beyond socio-economic surveys and organisational and financial questions. Second, there is hardly any documentation of the experiences of executors of the policy (administrators, engineers, etc.) both in terms of success achieved towards this end as well as the identification of various kinds of practical difficulties involved in the process. Third, the research procedure and methodologies which are currently in vogue and concern with productivity and equity aspect, have hardly been discussed in India by way of organising workshops, research fora, etc., with a view to reviewing their relative strength and weaknesses. In view of the existing state of affairs, we propose to invite two sets of experts for the workshop. One set would consist of administrators, engineers and others who have actual experience of operationalizing the concept of equity and productivity in the field. The other set would include researchers, with an inter-disciplinary orientation, having conducted (or conducting) empirical studies pertaining to equity and productivity preferably at a micro level.

The major thrust of the workshop would be to carry out detailed discussion among the various experts - practitioners (administrators, engineers, etc.) as well as the researchers, over the issues relating to productivity and equity in irrigation systems in India. It is expected that the contributions from the participants would help in analysing, at length the existing state of research and suggesting ways and means for improvements in irrigation systems in India. The sessions alongwith the topics to be discussed would be as under :

Session I - Research Methodology

The relevance of inter-disciplinary approach to study equity and productivity aspects with involvement of the following issues :

i. Theory and concept of productivity and equity. Are there any major logical weaknesses or any major ommissions?

ii. Is there any room for improvement in research methodology for the analysis of productivity and measurement of equity?

Session II - Administrative measures for augmenting productivity levels and enforcing equity :

i. Measures taken.

ii. Difficulties experienced.

iii. Net result obtained.

(Administrator/Engineer invitees would be expected to present specific cases in the above context)

Session III - Micro-level case studies by researchers

i. Choice of the problem.

ii. Operationalisation of the concepts used in research.

iii. Methodology adopted including method of measurement.

iv. Findings arrived at.

(Researchers of various disciplines like social scientists, engineers and agronomists will be requested to present micro-level case studies based on empirical data)

Session IV - Summary conclusions and recommendations

(1)

PRODUCTIVITY AND EQUITY IN IRRIGATION SYSTEMS IN INDIA : ANALYTICAL AND EMPIRICAL ISSUES

P. K. RAO*

A B S T R A C T

There is urgent need for the assessment or irrigation efficiencies in a fairly comprehensive manner so as to provide details of component-specific efficiencies in the main agricultural seasons in different geographic regions within the command area of each of the major and medium irrigation projects. This information, when transformed into marginal productivity implications (with the detailed break-up corresponding to the above) enables the policymakers to attempt to maximize economic welfare by choosing a mix of policy intervention strategies (involving amongst others, physical structures, management and institutional innovations). The role of uncertainty and risk element in determining productivity is analysed. This aspect, in conjunction with equity factor generates alternative production - possibility - frontiers leading to articulation of trade-off frontiers in relation to different intervention strategies and investment decisions. Towards the last part of the paper, the quality of information relevant for the assessment of productivity and equity alongwith administrative and other institutional ramifications is discussed.

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The objective of this paper is first to articulate issues in formalising conceptual framework within the context of regional and sectoral development; subsequently the operational problems involved in translating the desired/desirable objectives into practice are discussed. Here productivity and equity are analysed with reference to those applicable for water as the key input in the development process.

One of the obvious and simplest approaches to the concept of productivity of water is physical aspect; change in agricultural production of specific crops (in quantity terms) with changes in availability/water use. This, however, is conditional upon the geographic location, agricultural season, choice of crop; it may also be distinguished in average and marginal terms, at the farm level and for the sub-regions or the entire command area of an irrigation system. Since the physical productivity by itself is not necessarily reflective of welfare of producers/consumers in a society, it is highly desirable to analyse within the framework of economic dimensions.

The major problem in devising irrigation management schedule so as to maximize productivity of water assessed in economic terms (value of production) is that the assessed productivity would be subject to random variations in agricultural commodity prices and hence the need to recognise a stochastic parameter in productivity. Strictly from a general welfare point of view, we should seek policies which result in Pareto-optimal welfare within the defined framework of welfare of different sgments of the society. Productivity implications can be viewed in this approach, when we are referring to aggregate/sectoral/national policy issues : the direct and indirect net benefits to society as a result of varying levels of economic productivity. For the present purpose we confine our attention to productivity considerations within a given irrigation project/command area and therefore the global welfare parameters need not be a major concern.

At this stage it is necessary to clarify the policy framework within which we propose to analyse productivity aspects. This is necessary for the purpose of operational relevance of the concept of productivity. If the command area is fixed in size and defined in terms of agro-climatic and geo-hydrological features, the productivity of water can be affected by choice of appropriate interventions in i) release of water into different sections of the irrigation network; ii) choice of appropriate technology for water distribution system selective lining of canals, control structures etc; iii) institutional mechanism for effective enforcement of water distribution rules - administrative component and role of farmers organisations iv) monitoring and concurrent evaluation of performance of system and different components; v) improved on-farm efficiency of water use and choice of crops; vi) augmenting water supplies with ground water and rain water; vii) other economic interventions in the form of incentives for higher productivity, price fixation for different commodities in terms of support prices etc. Some of the points given above refer to economy in the water management system.

Efficiency Aspects:

The definition of efficiency in irrigation system could be broadly characterised either in terms of hydrogeological (i.e. water use efficiency or irrigation efficiency) or socio-economic (Productivity/growth and social justice) parameters. As recommended in a recent National Seminar at the Administrative Staff College of India on Multi-disciplinary Organisation Structure for Irrigation Projects (October, 1981) :

"In the ultimate analysis irrigation efficiency is to be measured with reference to the primary objective of irrigation, namely, irrigated agriculture which is the end product of a long process. Thus, the efficiency of the system as a whole can be measured via efficiency of irrigation agricultural production. The latter can be expressed in terms of output per unit of the scarce factor, which may be land in some cases and water in others. More

specifically, the measure of efficiency can be a ratio representing the relationship between physical output projected in the appraisal report, or any other revised value accepted as a criterion. Defined in this way, efficiency of the irrigation system as a whole will emphasise the role which each sub-system plays in irrigated agricultural production."

However, attempts to evolve non-controversial definitions in precise terms about irrigation systems efficiency are bound to be met with considerable resistance as they cannot be divorced from relevant environmental, socio-cultural and political institutions. In specific regional economies market and non-market factors tend to effect any prespecified criterion of irrigation efficiency or water use efficiency in varying degrees. The crux of the problems lies in isolating the relative impacts of these factors and in evolving a pragmatic approach which would mean finding out a judicious mix of workable interventions. These could, for example, emphasise on appropriate safeguards on water rights, water pricing, guidelines for water distribution at the retail outlet, the basic structuring of release of water in terms of demand responsiveness and/or adhoc supply rules. A mix of these alternative choices in conjunction with other socio-political factors result in certain end-products in terms of agricultural production, agricultural income and its distribution across regions and sections of the society.

In respect of assessment of irrigation project efficiency, amongst the criteria suggested from the hydrological point of view of utilisation of water are : i) field application efficiency, ii) distribution efficiency, iii) conveyance efficiency, iv) tertiary unit efficiency, v) irrigation system efficiency and vi) overall or project efficiency. It is stated by Bos and Nugteren :

> "Water utilisation efficiency was used ... as the main criterion or characteristic of performance. The use of this single, normative judgement has the advantage that any physical or socio-organizational feature can be tested against the same yard-stick, while it also allows

> a simple prediction of the combined effects of these features when being contemplated for planning purposes. Criteria like crop yields or financial returns per volume unit of water were not applied .. as these would only partially reflect effects of irrigation ..."(p.12)

The risk in using water utilization efficiency *(WUE) as the main criterion for assessing the performance of irrigation projects is that this hydrologically determined characteristic when used for policy decisions, particularly investment decisions, may often lead to misallocation of investment : this happens when the target is to maximise WUE. Given the socio-economic features prevailing in a country (along with the projections for future - with an without the contemplated irrigation projects) it may be optimal, from the welfare point of view, to attain only a critical range of WUE (for example, it may work out around 50 per cent) particularly because the incremental costs of achieving higher WUE may not be commensurate with the incremental benefits. Financial return per unit water reflects only a partial effect of irrigation : the economic return (using social cost benefit analysis) per unit water is relevant in many situations to evaluate the impact of irrigation, particularly when the cost of providing additional water is evaluated in terms of social cost.

When the efficiency criteria are used for "evaluating the water utilization efficiency on existing projects and finding methods to improve system conditions or even optimize them" (p.72) (Bos and Nugteren), sufficient care should be taken to formulate properly what are given in a specific project to which improvement or optimization is sought. It would be erroneous to include cropping alternatives as possible choices, disregarding the market situation of different agricultural commodities, in order to optimise the project efficiency. The tendency to deploy the hydrological efficiency criteria to prescribe agricultural production should be avoided. These criteria are meaningful and useful when the agricultural production system is treated as given and then improvements to attain higher levels of different types of efficiency are explored (Rao)[2].

Equity Aspects:

According to Arthur Mass and R.L. Anderson[3]:

"equity is to govern the exercise of any discretion that canal officers have when they enforce orders and regulations for water distribution and to govern the legislators' discretion when they fashion these rules from formal concepts ....."

Operational equity in irrigation water availability in the command area is an important feature and common problem in most of the irrigation projects in India is the tailend problem. Farmers at the tailend receive no water at all or disproportionately small amount of water. It is a different question whether there was inappropriate demarkation of the command area in terms of its size and coverage of specific geographic regions. Another important aspect which is reflective of the equity problem is the gap between irrigation potential created and utilised (despite certain conceptual problems in defining these two terms). If the available irrigation statistics are to be taken seriously, there is terrible gap between the irrigation potential created with massive investments and the potential utilised. Even discounting part of the officially stated gap has motivated due to differences between Revenue Department and Irrigation Department, still the residual gap would be distributing as that would imply of non-realisation of benefits from considerable investments and more and more the inequitable utilisation of water. Its common that farmers at the upper reaches of the irrigation system resort to multiple wet crops whereas those at the tailends and are those outside the system realise hardly one-third of the benefits corresponding to the more privileged group.

A number of Committees, both State level and Central level, have visited the various projects to study and identify the maladies and to suggest remedial actions. The Irrigation Commission also dealt with the subject. Prominent among the many factors and deficiencies identified are:

i) Canals are not maintained properly and do not carry the designed discharges.

ii) Conveyance losses are heavy in some reaches necessitating lining.

iii) The outlet are not always located properly and cannot supply the designed discharge.

iv) Watercourses and filed channels are not constructed even years after the canals are ready. Where constructed, they are not maintained properly.

v) OFD works are not properly taken up.

There are several issues involved in the assessment of uncertainty in farm water supply. A reasonably accurate estimation of probability distributions of farm supply over time and quantity at a few different locations in the canal command could throw light on the expected value and variance of water availability in different periods of a season. However, data limitations are likely to forbid such an attempt. The existence of two-level rationing introduces an element of uncertainty in the sense that the probability of availability of requisite amount of water during any week at farm level is conditional upon the probability of required supply flowing into the channel in that period and if the numerical value of the later is low the value of the former is lower. This does not however, imply that there is a decrease in the expected value of water availability nor an increase in its variance in a given period as far as the farms at the tail-end (which constitutes nearly 20%) of the canal command areas. It could mean lowering of the expected value of farm supply for the other farmers, the magnitudes of reduction progressively increasing with the proximity of land to the canal head. This is a distributive justice requirement and since the compromise involved (if any) in growth/efficiency by production does not seem to be significant, the water rationing system merits its existence.

According to Reidinger[4]:

"Control over timing and quantity of water supply would enable the farmer to equate marginal revenues and costs

from water applied, and to eliminate one source of risk in planning his operations. Even without water control, a highly predictable and certain water supply would permit him to approach profit maximization with precise farm planning, and actual outcomes should closely match expectations. However, as the certainty of his water supply decreases, the farmer must reduce the level of all inputs, and thus output and profits, in order to decrease the chance of loss. Such risk adjustments sacrifice per acre output and profit for a higher probability of positive net returns.

"A similar risk adjustment can also occur in water management, resulting in a water-application rate well below the economically optimum level in order to assure that marginal cost, and certainly remains non-negative. Agronomic, climatic, and soil factors can, however, severely limit the possible reduction in water application rates. The farmer may therefore diversify his crop pattern as an additional risk adjustment and include drought resistant but low-valued crops, such as gram".

If the degree of certainty required in water supply is very large (exceeding probability say, 0.8), it is practically impossible to have a canal irrigation system simply because the incremental costs of ensuring greater degree of certainty keep increasing and may often not meet the incremental benefits viewed from a macro or regional policy view point. It should be noted that the theory given applies to probably a typical rational farmer, if one exists, who has no other objectives except profit; however, the decision-making process of different classes of farmers in a given agro-climatic region depends largely on their land holding pattern and probably only the rich class can consider the only objective, viz. profit maximization, whereas others have constraints like domestic consumption requirements (and feed and seed etc.) and in this case the marginality conditions do not hold (since maximization of $f(x)$ is not same as max $f(x)$ subject to $g(x) \geq c$, other things remaining the same). If farmers diversify the crop pattern as part of risk adjustment and produce grams (low-valued) there is nothing unwelcome about it in a socio-economic sense, as this production pattern is likely to benefit poorer sections of the community - additional supply of grams (and other inferior cereals) help reducing market price of food which is mostly consumed by the urban and rural poor.

According to Mellor et al[5]:

"Water will generally produce a higher return if it is spread relatively thinly. As more and more water is given per acre, the yield per acre rises, but returns per

> acre-inch of water decline. Thus the protective policy of making relatively small quantities of water available per acre ensures the highest returns".

This argument neglects assessment of net returns. The dispute stems from the divergence feature of individual and regional (or societal) welfare requirements, in the presence of externalities. Net returns for a given farmer may increase in a certain critical range of application of water, but net returns in a community sense do not increase when the situation is characterised by fixed scarce water availability.

Information Base:

It is not sufficient to obtain data regarding the area irrigated from each source. A greater detailed analysis of availability of water by each source in different periods in different years would go a long way in improving the quantity and quality of data. It is useful to quote Rober Wade[6].

> "As irrigation projects are pushed into increasingly less (hydrological reliability-wise) favourable environment the information system will become an increasingly part of the system of water control.
>
> 'Warranted duty' the area that can be "satisfactorily" irrigated by one cusec of water flowing continuously throughout the plant growth cycle, and is normally defined for two types of crop-heavily and lightly irrigated and for two seasons Kharif and Rabi. 'Actual duty' should refer to the area actually irrigated (in the sense of brought to harvest with the help of irrigation divided by the actual quantity of water supplies (in cusecs).

The warranted figures are rules of thumb worked out on the basis of experience; they are not based on experimental evidence and they simply ignore the link between irrigation requirement and soil type, stage of crop growth, rainfall etc; further the figures take no account of the connection between more or less water per acre, and more or less output acre or per unit of

water - water is simply 'irrigated' or 'unirrigated'. Warranted duty is devoid of economic and agronomic significance.

The three main parameters which engineers managing the irrigation system use are : i) the area irrigated, specified according to area under heavy irrigation crops/light irrigation crops; ii) the duty; and iii) the quantity of water used.

When, as in the second crop season there are large extensions of both heavily and lightly irrigated crops on ground, the calculation of duty is made by assuring that one heavily irrigated acre take twice as much as water as one lightly irrigated acre- assumption not based on experimental evidence".

The Irrigation Commission as well as several other expert committees strongly urged the urgent need for improved hydrological data base at different levels of the irrigation systems, for evolving rational policies of water management. It must be noted that the information system is not to be confined only to primary data but should also be composed of information that can be generated by monitoring, concurrent and ex-post evaluation of different aspects of an irrigation system. The lack of effective monitoring and evaluation system is the single most important factor affecting the efficacy of implementation as well as rationalisation of water management policies for improved productivity and equity.

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(2)

Irrigation Management: Ends, Means and Opportunities

Robert Chambers

Abstract

Views differ about objectives and criteria for irrigation and irrigation management - between individuals, groups, disciplines, professionals and departments; according to whether one or several objectives and criteria are considered; according to who is meant to benefit; and according to where objectives and criteria are located on long causal chains. As a practical framework, five focal objectives and criteria are proposed : productivity, especially of water; equity, especially in its distribution; long-term stability, both environmental and through maintenance of works; carrying capacity (livelihood-intensity), reflecting the size of population supported at a decent and secure level; and well-being, including health, amenity, nutrition and psychic factors. Measures to optimise achievement of these objectives include decisions about the size and location of area to be irrigated; changes in farm size; the scheduling and delivery of water; choice of cropping system and crop zoning; the frequency with which different zones receive irrigation; the staggering of cultivation; and the spatial and temporal spread of cultivation rights. Bringing this repertoire to bear, there appear to be rather few serious conflicts between the objectives. Perhaps the main one is between productivity and equity where high transmission losses reduce the productivity of system water distributed to tailends, but this is often offset by the highly productive use of groundwater supplied by seepage losses. In contrast, complementarities are very strong, especially with redistribution of water from head to tail which can at once be more productive, more equitable, reduce waterlogging, support

more livelihoods, and enhance well-being. Many constraints on optimising are linked with who gains and who loses from current practices, and who would gain and who would lose from changes. Facing these questions, the approach of practical political economy seeks realistic opportunities by asking how all can gain, or how losers can be reconciled to their losses. Three major problems and opportunities are presented by first, the professional training and incentives of irrigation managers, second, the search for ways in which headreach farmers can gain while receiving less water, and third, the purchase and distribution of land to landless and very small farmers at the time when irrigation comes. To proceed further, four next steps are proposed.

This paper is an attempt to explore objectives and criteria for irrigation and irrigation management, to state some of the principal means for achieving them, and to identify practicable approaches for optimising performance. The main attention is to South Asia, especially India, and to canal irrigation; but much of the discussion could apply also outside South Asia, and some of it applies to lift irrigation. 'Irrigation management' refers usually to the operation of irrigation, but planning and design are sometimes also embraced. An 'objective' is an 'end' or purpose, especially of irrigation generally, an effect or impact which it is intended to have, while a 'criterion' is a standard or measure of good performance, especially in irrigation management. In common usage, the two often overlap, as with 'productivity' and 'equity'.

The Quest for Criteria

The first task is to identify and agree objectives for irrigation and criteria of performance which can be used for planning, design and operation. This task is complicated by different views about objectives and criteria. For example, asked to write down their first criterion for good irrigation management, or their first objective, different people would give different answers. Five points can help to explain why this is to be expected, and also lay out some of the issues and analysis.

i. different views

Each group, discipline, profession and department has its own immediate concerns. While there would be exceptions, something like the following first immediate thoughts, reflecting the personal and professional interests of the respondents, might be expected on a first criterion for irrigation management :

Type of person	possible first criterion of irrigation management
landless labourer	increased labour demand, days of working and wages

Type of person	possible first criterion of irrigation management
farmer	delivery to his farm at low cost of adequate, convenient, predictable and timely water for his preferred farming practices
irrigation engineer	efficient delivery of water from head-works to outlet
agricultural engineer	efficient field application of irrigation water from the outlet to the root zone of the crop
agronomist	'The purpose of irrigation is to create and maintain the optimum moisture regime for plant growth and in particular to maximise production of that part of the plant which is the harvestable product' (Willens 1975:1)
agricultural economist	high and stable farm production and incomes
general economist	a high internal rate of return
political economist	equitable distribution of benefits from a project especially to disadvantaged group
sociologist	participation of irrigators in management

ii. the single criterion trap

The question requires only one criterion or objective but many criteria, and many objectives are possible. It is then scarcely surprising that people would differ in what they put first. After careful reflection, lists of criteria or of objectives might be agreed, with much commonality, between respondents from

different disciplines. But long lists are difficult to hold in the mind. One struggles to simplify. Moreover, for operational purposes, not many criteria can be handled. The trap of the single criterion is tempting : Thus in the words of a distinguished and successful irrigation manager, 'High productivity is the key ... to paraphrase Matthew, 'Seek ye first production and all these things shall be added on to you' (Giglioli 1968:9). This does not assume that production is necessarily an end in itself, but that through it other ends or objectives ('all these things') will be achieved. The two criteria that are most commonly stated singly are, first, high production or productivity, as in this example; and second, efficiency of water supply.

iii. how many gain or lose and who they are

Objectives and criteria are often expressed in terms of direct benefits to 'farmers' or 'irrigators'. But objectives may include all those who are affected, or who might be, or might have been, by a project and its management. Besides the (usually assumed to be male) farmers, this includes women, children, tenants, sharecroppers, landless labourers, and migrants attracted seasonally or permanently. Beneficiaries are also in some sense staff of departments working on irrigation, and those who attend conferences to discuss irrigation. Those who are harmed by a project or its management (for example those displaced by a dam) are also part of the calculus. Objectives and criteria may thus be narrow, limited.

iv. objectives, criteria and causal chains

A further reason why different criteria and objectives would be given is the length and complexity of the causal chains involved and the many points at which they can in principle be measured or assessed.

At the extreme of the general level of 'objective', there is the overarching question of the purpose of life and the purpose of

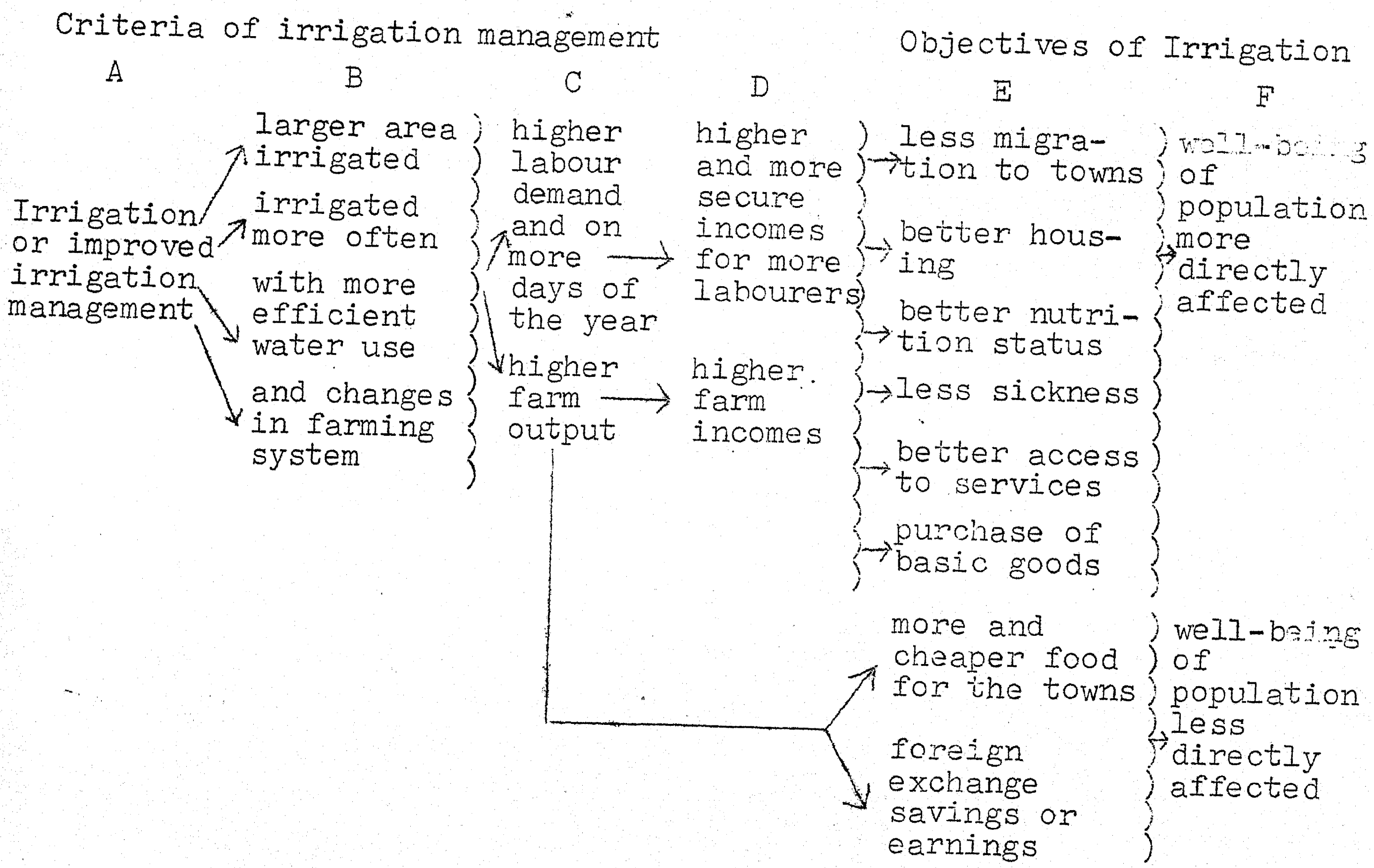
development. Perhaps all would agree that irrigation and good irrigation management should contribute to development, even though not agreeing what development is. At an abstract level, expressions like 'enhancing the quality of experience' may embrace a dimension of supreme importance, but much of what that refers to is difficult to relate to the more material world. Perhaps, becoming slightly more concrete, most people might agree, in some sense, on an objective of well-being especially for those who are less well off, and that those who are deprived should have more of what they want and less of what they do not want. Becoming more concrete still, there is the World Bank's definition of rural development :

> 'Rural development is a strategy designed to improve the economic and social life of a specific group of people - the rural poor. It involves extending the benefits of development to the poorest among those who seek a livelihood in the rural areas. The group includes small - scale farmers, tenants and the landless'.

(World Bank 1975 : 1)

The World Bank definition of rural development, does not, however, include wider national objectives for the economy and the society which may include : producing cheap food for urban areas; earning or saving foreign exchange; settling surplus population; and so on.

Here it may help to think of causal sequences and how objectives and criteria intersect with them. Some hypothetical relationships can be presented in causal sequence from left to right:



Several observations and qualifications arise from this diagram :

first, it only picks up some a sequences of effects of irrigation. There are others, such as direct health effects.

second, each arrow postulates a cause-effect or input-output relationship. Thus A-irrigation or irrigation management is only an input, but the items under B are both outputs from A and inputs to C, and so on, until the chain of input-output relationships ends in wellbeing for the population affected, whether directly or indirectly.

third, the outputs result from much more than just the input in the diagram. (e.g. higher farm output may result from technological change, weather, credit, or a host of other factors and their combinations). This may especially be so in the links between income and well-being, with an indeterminancy which is not special to irrigation.

fourth, the diagram assumes benefits, but effects can also be disbenefits (worse nutrition, more migration to towns, lower incomes etc.).

finally, the criteria of irrigation management per se are on the lefthand side of the diagram, while the objectives or impacts intended from irrigation are on the righthand side. Since the arrows are hypotheses, and may or may not be valid, case by case, it is possible to have irrigation management which is good by its own criteria, without achievement of a desired impact or objective, or even with a negative effect (e.g. if productivity rises but nutritional status declines).

v. the need for a practical framework

A final reason why different people can be expected to state different objectives and criteria is the lack of a universally accepted normative and practical framework for evaluating the planning, design and management of an irrigation system. Many sets of objectives and criteria have been proposed, and some people (*mea culpa*) keep on changing the ones they suggest. Thus we have, for example

productivity (of water)	economy (production)	productivity(especially of water)
equity (in its distribution to users)	equity(benefit distribution and farmer participation)	equity (especially of water distribution)
stability (in maintaining the water supply)	efficiency(water use)	long-term environmental stability
continuity(in water use throughout the year)	(Early 1981:1 describing potential benefits of irrigation system performance in most cases not fulfilled)	at least cost
carrying capacity (in sustaining population at acceptable levels of living)		(Bottrall 1981:26, stating the assumption that the main concern of an irrigation manager of a large irrigation system should be to achieve an optimum balance between these goals. He also mentions cost recovery and employment as possible criteria(*Ibid* 26 and 43).
(Chambers 1977:361, on what a list of objectives of irrigation in conditions of South Asia might include)		

Other lists have included convenience to irrigators, utility to irrigators, and quality of life.

Whatever the objectives or criteria, there will be a cost side, and a benefit/disbenefit side. The cost side is relatively well understood, whether in terms of irrigation water at the point of diversion or storage or elsewhere, or of financial, staff or management costs, or of opportunity costs of not using resources elsewhere or in other ways. I shall therefore concentrate on benefit/disbenefit side.

On this benefit/disbenefit side, there seem to be three needs: first, objectives which capture the major benefits/disbenefits which can be attributed to irrigation and irrigation management; second, operational criteria which can be assessed or measured and used to improve, monitor and evaluate irrigation planning, design and operation; and third, parsimony, in seeking objectives and criteria which are few but focal enough to capture the major dimensions and to act as proxies for others. The resulting short list should be useful for thinking about irrigation planning, design and operation, and the criteria included should be usable for the management of irrigation systems.

The list proposed here has five objectives which slice the reality at different points and in different ways, and which to varying degrees can be made operational as criteria. No doubt this list can be improved upon; for the time being it may at least provoke discussion, dissent, and progress towards something better. The five objectives are :

productivity
equity
stability
carrying capacity
well-being

It is arguable that it would be useful to add convenience or utility of water supply to farmers, but these are partly subsumed by productivity and equity.

Five Focal Objectives and Criteria

i. productivity

Productivity means output divided by input[1]. In common parlance, it is sometimes used to mean, quite simply, production. Thus if someone were to say of an irrigation system, 'productivity has gone up', they may mean that production has gone up. Strictly, however, productivity will have gone up only if production has gone up per unit input.

In practice there are many possible meanings and measures for productivity. At the operational level, for purposes of monitoring, management and evaluation, the best measure of productivity will vary from system to system, and according to immediate purpose. A common and often useful interpretation of 'productivity' on an irrigation system is a measure of production per unit of water. Lenton(1981) has described various operational measures. He points out that productivity performance can be measured by water delivered, area irrigated, yield, or income, and the measures can be at the level of farm, of an outlet, or at higher levels of aggregation. Which of these is best will depend on circumstances. The denominator for the productivity of water can also be taken as water in the root zone, at the farm gate, at the outlet, or at higher points in the system, including the point of storage or diversion. Thus productivity can be defined:

a. if water is a limiting resource

$$\text{productivity} = \frac{\text{water delivered (to outlet, farm gate, or root zone) or area irrigated or production, or yield per unit area or gross income or net income}}{\text{quantity of water available or issued at the point of diversion or in the storage, or issued from the headworks, or at points lower in the system (in each case with or without rainfall in the command area)}}$$

b. if water is not a limiting resource

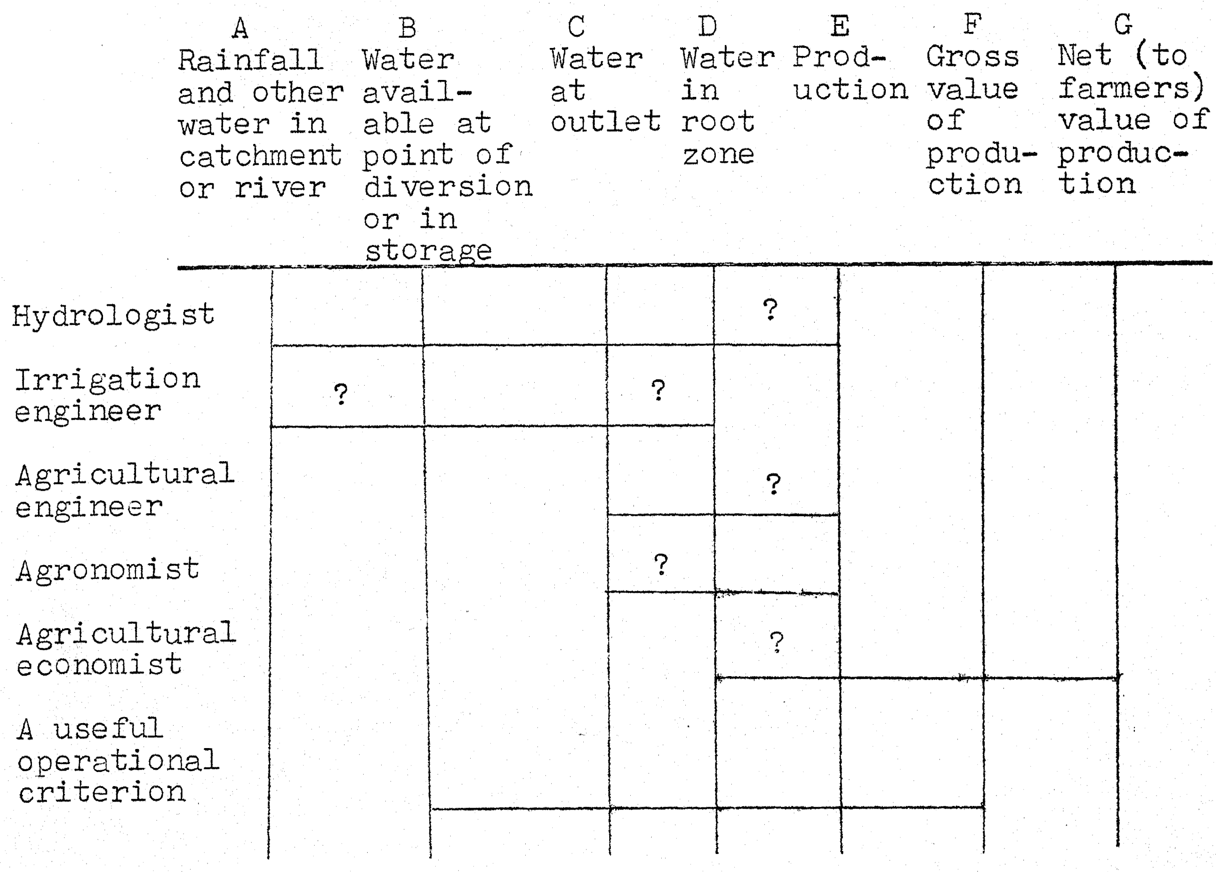
$$\text{productivity} = \frac{\text{production or gross income or net income}}{\text{land or labour or capital or management or other scarce resource}}$$

In this case, good irrigation management will still lead to high productivity, but the measure of productivity will be different.

All of these versions of productivity are in principle measurable. Which is best operationally depends on the relative scarcities of resources, the cost and accuracy of data collection, the timeliness with which it can be analysed, its utility for management purposes once analysed, and the relationships between it and other criteria and benefits.

Taking water as the scarce resource, some of the possible measures of productivity, earlier along the causal sequence, are thus, in technical terms, efficiencies (see e.g. Bos and Nutgeren 1974), that is ratios of water at a point of delivery to water at a point of issue. These correspond interestingly with the objectives or criteria which it was supposed above that different persons and specialists might give for good irrigation or good irrigation management. Diagrammatically, these can be shown as follows:

Points of Input and Output Measurement for Different Professions and Disciplines



At both general and operational levels, the most widely useful meaning and measure of productivity, where water is limiting, may be the gross value of production (which can be measured through crop-cutting exercises and surveys of prices) divided by the water available at the point of storage or diversion. This sounds straightforward, but hardly anything to do with water is simple, except perhaps drowning. The techniques and problems of measurement of productivity of water and of the operational use of such measurements deserve separate analysis and discussion. The most serious complication is probably the conjunctive or independent use of groundwater within a command area, making it difficult to know what irrigated production to attribute to canal water, what to groundwater deriving from seepage of canal water, and what to groundwater deriving from other sources.

ii. equity

Equity is a more difficult concept. The Shorter Oxford English Dictionary calls it 'The quality of being equal or fair; impartiality; even-handed dealing. That which is fair or right..' Applied to the practices of irrigation system planning, design and management, this raises the question: how equal?

This question has received many answers. As with the doctrine of prior appropriation (that whoever first exploits a resource has a right to continue to do so), inequality comes through usage to be regarded as a right, even if not entirely fair. Topenders, or early comers to an irrigation settlement project, gain customary usage to water which they then come to regard as their right, even though it usually means less water or no water to tailenders or late comers. Offsetting this and often conflicting with it, is the widespread doctrine of proportionate equality (Anderson and Maas 1978:41) which identifies equity with the supply of water in proportion to land surface area. In this doctrine, the inequality of landholdings is accepted and water is allocated, as in the warabandi systems of North-

west India (Malhotra 1982a and b), to each farmer in proportion to landholding size. Thus those who are already better off, with more land, get more water; and those who are worse off, with less land, get proportionately less; and those who are worst off, with no land, get none at all. In South Asia, as elsewhere, both doctrines can be found applying on the same system: headreach farmers have sometimes (as in the Cumbu Valley of the Periyar Vaigai Project in Tamil Nadu) established privileged rights to water, while lower down the project area, the theory of water distribution is that it should be proportional to land.

In India, the inequity of both doctrines is increasingly questioned. The doctrine of prior appropriation is challenged by attempts to redistribute water from headreaches to tailends (see below). About the doctrine of proportionate equality, doubts were raised at the workshop on water distribution practices held at the University of Roorkee in July 1982 (IWRS 1982) by three senior engineers, one of them asking why, if hospitals were for all, irrigation water, similarly provided from public funds, should not be for all also. Nor is proportionate equality always enshrined in traditional practice: in the village of Duli in North Arcot District, Tamil Nadu, it is said that when tank water is short it is allocated for an equal small area for each landholder regardless of landholding size. Further, two projects have recently been pioneered which apply the more equitable principle of equal personal rights to water: one under small tanks; and one with lift irrigation.

The small tanks example is the Sukhomajri project (Seckler and Joshi 1981; Malhotra 1982:61-66) near Chandigarh where each household (defined as a chula or hearth) has an equal water right, including landless households. In the words of S.P. Malhotra (1982:66) :

> 'A new method was designed to allocate water first to the 'people' and only secondarily to 'land'. Some were found to be unable to utilize a part or whole of their share. For their benefit, a suitable mechanism,

> for marketing the surplus, has been evolved. The method ensures a water right for every family, even if it is landless, and has been named as haqbandi'.

The second example, with lift irrigation, is the Gram Gourav Pratisthan, started by Vilas and Kalpana Salunke at Naigaon in Purandar Taluka near Pune (Chambers 1981; Morehouse 1981; Parulkar 1982). Here the allocation of water is based on the number of members in a household, subject to a basic financial contribution per household member and to the household having adequate land under command of lift irrigation. Since in practice most households have land and most have been able to raise subscriptions, the resulting allocation of water may achieve quite a high degree of equality per person.

On canal irrigation, however, such equality, however desirable, is usually a long way off. In part of Maharashtra, full water is allocated to the first 2 hectares, with diminishing allocations per hectare as hectarage rises above 2 hectares (personal communications, D.R. Arora and E. Stains). But elsewhere, water distribution is far from meeting even the criterion of proportionate equality; the disadvantages of tailenders are notorious. Research in Sri Lanka has shown concentrations of wealth, influence, tractors, and services at the tops, and conversely poverty, lack of influence, lack of farm power, lack of services, and disadvantages such as higher pupil:teacher ratios in schools, at the tails (Moore et al. 1982). In India, research by WAPCOS[2] (reported in Lenton 1982) on the Mahanadi Reservoir Project in Orissa has found a gradation in paddy yields on outlets from 1.54 tons at the very head down to only 0.22 tons at the very tail. Even on the Upper Ganga Canal, where warabandi is practised, recent research on one distributory reported by Padhi and Suryavanshi (1982:26) has shown a contrast between an irrigation intensity of 119 at the head, and only 72 in the middle and 68 at the tail, accompanied moreover by a much higher concentration of sugarcane at the head. On other systems, tailends which are meant to receive water never do, or have only recently received it as a result of the redistribution of water,

such as those of the reforms of Integrated Water Management in Andhra Pradesh (Ali 1981). In these circumstances, of gross inequalities in the supply of water to different parts of irrigation systems, it is not surprising that attempts to improve management limit themselves at most to the target of the principle of proportionate equality, to the supply of water proportional to land, since the application of even that unequal principle would be far more equitable than current practice.

For operational measures of equity, Lenton (1981) has made proposals parallel to those for productivity, following the principle of proportionate equality. These would measure the equity of water delivery, of area irrigated, of yields, or of income at different points in the system, expressed as performance at a tail reach location (on a watercourse, or minor canal, or distributory, or branch canal, or main canal) divided by performance at a head reach location. Performance on different parts of a system would be indicated by taking heads and tails, as desired, of watercourses, minors, distributories, branch canals, or main canals.

For both general and operational purposes, equity can, then, be taken to mean more rather than less equal benefits from irrigation management, to more rather than fewer irrigator families, with priority to the disadvantaged.

iii. stability

Productivity and equity taken on their own do not encompass changes over time. Yet the sustainability of productivity, equity, and other benefits, is important. The term 'environmental stability' (Bottrall 1981) is clear, and refers to the prevention or minimising of physical changes with adverse effects, such as water-logging, leaching of nutrients from soils, salinity, erosion, silting, the 'mining' of groundwater, infestations of weeds, and pests and diseases. Maintenance of physical works is another vital aspect of stability.

The objective of stability can, then, be defined as the sustained achievement of other objectives. As an operational criterion, it can be assessed through the monitoring of appropriate physical measures such as groundwater levels, through the inspection of works, and through trends in performance indicated by other criteria.

iv. carrying capacity

Carrying capacity refers to the performance of an irrigation system in making possible adequate, secure and decent livelihoods. One way of describing it is as livelihood-intensity, the ratio of acceptable livelihoods generated or supported, to water or other scarce resources. Whereas equity, as defined, refers to fairness and relative equality in the distribution of water and benefits, carrying capacity refers to the population enabled by an irrigation project to live above a minimum level. The preoccupation of irrigation management with production has tended to obscure the benefits to the poorer people for whom irrigation may create livelihoods through more employment, higher wages, and income spread through more of the year. Carrying capacity should capture some of the wider effects of irrigation and irrigation management on the disadvantaged, including women (Agarwal 1981), tenants, sharecroppers, the landless, migrant labourers, and people who have migrated from rural areas to urban slums and who may return if there are good opportunities for a livelihood.

Since carrying capacity in this sense is not yet an accepted objective or criterion, three points of elaboration are in order. First, carrying capacity is affected by planning and design. Where unoccupied land is settled under irrigation, this is through the size of holding and cropping pattern; and where land is already settled, through the size of geographical area it is decided to irrigate (affecting more or fewer farmers). The planned water duty is a central decision here. Second, where food and income flows to households are more stable under

irrigation than with rainfed agriculture, the acceptable level of livelihood (expressed as mean income) may be lower because there is less need for larger surpluses to carry through bad years. Third, higher intensities of irrigation may provide more continuous employment for those without land, and more frequent flows of income to those with land; thus the more intensive irrigation of a smaller area may be more livelihood intensive than the less frequent irrigation of a larger area.

The measurement of carrying capacity is not easy. The simplest measure is to count the population directly supported by a project, but this is complicated by the concept of an adequate, secure and decent livelihood: some may be supported by a project at an unacceptable level, while others may be migrants who achieve an acceptable level by virtue of combining seasonal employment on the project with work elsewhere. At this stage it may be less important to try to measure levels of carrying capacity operationally, than to use it and livelihood-intensity as general objectives or criteria in analysis and decisions to influence directions of change - towards greater livelihood-intensity and higher carrying capacities.

v. well-being

These four objectives and criteria pick up many of the benefits and disbenefits of irrigation and irrigation management, but not all. There remains the human well-being of the people affected. Productivity, equity, stability and carrying capacity, may all contribute to this, but do not encompass it all.

Much depends on what people themselves value, but perhaps four aspects of well-being, might command their agreement and that of outsiders:

i. health. The adverse health effects of irrigation through malaria, schistosomiasis (though not in India), and sometimes drinking water, are well known.

ii. amenity. Irrigation can improve amenity through water for washing, and bathing, through raising groundwater levels so that water for drinking and other domestic purposes does not have to be lifted so far, and so on.

iii. nutritional status, which can be affected positively or negatively by changes associated with irrigation.

iv. psychic factors, such as a sense of control of the environment, freedom from domination, participation, and other non-material aspects of the quality of experience, depending upon what people themselves value.

Some, but not all, of these are susceptible to measurement.

Repertoires for Optimising

Many measures are or could be used to improve the planning, design and operation of irrigation systems to optimise productivity, equity, stability, carrying capacity, and well-being. They include many which will not be considered here, including engineering works, on-farm development, methods of field water application, and farmer participation. This is not to suggest that these are unimportant. They are, however, relatively well understood and well documented. The focus here will be on the resources or dimensions of land, water, crop, location and time, which taken together open up a range of options which are, I think, quite often thought about by experienced planners, designers and managers, but which do not seem to be written down and considered together.[3]

These dimensions or resources present options as follows:

dimension or resource	options presented by
i. land	size and location of area to receive irrigation
ii. farm size	planning new settlement, or redistributing land
iii. water	the scheduling and delivery of water
iv. crop	choice of cropping system, including crop zoning
v. location and intensity	frequency with which different zones receive irrigation
vi. timing	the staggering of cultivation
vii. spread of cultivation rights	rights in different places and/or at different times

i. size of area to be irrigated

In analysing the size of area to be irrigated, it is useful to start with Keller's (1981) membrane concept. He writes that he likes to think of

> 'the physical objective of an irrigation project as being to stretch the water like a membrane uniformly over the intended command area. The irrigation project canals, farm watercourses, and field ditches form the rigid framework needed to push the membrane out........ an adequate irrigation system and effective management of it are essential to stretch and hold the membrane in place. A uniform membrane over the entire command area represents an efficient and equitable system..'

Planners, he says, design projects with different concepts of 'membrane tension', reflecting degree of designed water scarcity. The designed water scarcity which is optimal for crop growth per unit area is not the same as the designed water scarcity which is optimal for crop growth per unit water. For one thing, as Keller points out, most field crops will produce about 90 per cent of potential yield when only supplied with about 75 per cent of peak water requirements. The size of area to be irrigated thus has major implications for the productivity of water. Size of area is also closely linked with the other options -

of farm size, water scheduling, cropping system, location and intensity of irrigation, staggering, and on some small systems, spatial and temporal variations in cultivation rights.

ii. farm size

Farm size is a variable that can be controlled only where new land is being settled, or where land is redistributed (see pages xx - xx below). Farm size most strongly affects:

productivity:	the well documented inverse relationship of Indian (and much other) smallholder farming, that productivity per unit of land declines with holding size, suggests that (at least over some ranges of size) productivity will be higher the smaller the farm units(Saini 1979:112-116, 122-3, 152-3).
equity:	more, smaller landholdings will within limits be more equitable
carrying capacity:	more, smaller landholdings may provide more livelihoods per unit water.

iii.scheduling and delivery of water available

The scheduling and delivery of water is perhaps the most powerful tool for optimising benefits from irrigation, and is receiving increasing attention. The classification of types of scheduling in South Asian conditions is still, however, at an early stage. In India, the normal form of comparative analysis is not limited to or even determined by, types of scheduling, but is rather based on regional variations of total irrigation and cropping system (e.g. Saksena 1982). Of these, the best known and best documented is the warabandi system of Northwest India (Reidinger 1980; Malhotra 1982a and b), with its (in Keller's terms) high tension membrane and rotations between minors and between farmers, who receive less water than they need for the land they have. Second, there are the systems in areas of Western India where water is meant to be supplied only to those who indent for it. Third, there are the systems of

South India where land is localised, that is, zoned, for either irrigated wet (usually paddy) or irrigated dry crops. This is nothing like a full review of typology, but its significance is that with the partial exception of northwest Indian warabandi, it is not a classification in terms of water scheduling. It is no substitute for analysis and classification of different types of water delivery schedule.

For scheduling proper, the usual broad discrimination in India as elsewhere is into three types of delivery:

continuous flow rotations demand systems	American Society of Civil Engineers 1980 Mathur 1982

Kathpalia (1980) distinguishes systems of upstream control which distribute the available supply of water, and downstream control which is based on demand. There is some correspondence here with the categories used by Replogle and Merriam (1980) for conditions in the United States. They consider the frequency, rate and duration of water supplied and distinguish between schedules which are rigid and supplier-controlled, and those which are flexible and user-controlled, as follows:

a. rigid, predetermined, supplier-controlled:

- i. constant amount- constant frequency(rotation schedule)
- ii. constant amount- variable frequency(modified frequency rotation schedule)
- iii. varied amount - varied frequency (varied amount rotation schedule)

b. flexible, user-controlled:

- i. demand
- ii. limited rate demand
- iii. arranged (as to date)
- iv. limited rate arranged
- v. restricted arranged
- vi. fixed duration - restricted arranged

These may not be useful categories for India, but the point of listing them is to raise the question whether comparative analysis of actual and potential scheduling practices on Indian canal irrigation might not lead to a similarly extensive and useful, though different, classification. The Roorkee Workshop on water distribution practices (IWRS 1982) provided some material for this, and reinforced the case for such an analysis and for developing methods for deciding what scheduling is best in what conditions.

In terms of options, it is common for the scheduling procedure to be changed as a season passes and as water becomes scarcer. This is routinised in the Northwest Indian warabandi (Malhotra 1982a and b) and also in an elaborate way in Valencia in Spain (Maas and Anderson 1978:25-42), where distribution starts according to the principle of proportionate equality(emphasising the equity objective) but later with increasing scarcity shifts more to priority for the more valuable crops (emphasising minimising losses, which is the productivity objective). Thus, subject to the physical capacity of the system and the established rights of irrigators, it is not necessary to opt for only one form of scheduling.

Many of the implications of the scheduling of irrigation water for productivity, equity, stability, carrying capacity and well-being are too obvious to deserve elaboration at this point.

iv. location and intensity of irrigation

The 'membrane' can be stretched over different areas, and with different frequencies to allow different intensities of irrigation. Patterns of application vary between high intensities for the whole of a command, where water is adequate for that, to stretching the membrane over different areas in rotation, which can be described as the sequencing of zones.

The sequencing of zones can be overlooked as an option, but it is quite common in South India. One example is Lower Bhavani

in Tamil Nadu(Sivanappan et al 1982). On this project, many short distributories take off from a long canal. They are numbered even and odd, and water deliveries alternate by seasons between all the odd numbers and all the even numbers. Another example is the yaya (ayacut) under Tissawewa tank in Hambantota District in Sri Lanka. There, in the second, yala, season, the water diverted and stored in the tank proved inadequate to irrigate the whole area. This led to a decision to adopt a system of irrigating only two thirds of the area each yala, so that each cultivator had two yalas in succession and then missed one.

Location and intensity of irrigation have implications for all five objectives and criteria. In particular, high intensities tend to generate year round livelihoods for labourers, while sequencing of zones may be more equitable than leaving some potential irrigators out altogether.

v. crop choice and zoning

The crops to be grown is a major choice. In high tension systems where the water supplied to a farmer is inadequate to irrigate all his land, the choice of what crop to grow with limited water can be left to the farmer, as it is with warabandi in Northwest India. Elsewhere, deliberate crop zoning is found in the localisation of South India into irrigated wet and irrigated dry areas; in the block system of Maharashtra (Gandhi 1981:10-11) where blocks of land are sanctioned for particular crops; and in the phad system of Maharashtra (Patil 1981) where originally at least each farmer held land in a number of blocks. Each block has its own crop (which can be suited to its soil characteristics) and receives its own appropriate water supply.

Crop choice and zoning have implications especially for productivity, equity, stability and carrying capacity. The well-known and familiar condition is where ample supplies of water are (unproductively, inequitably) appropriated in the head reaches to provide heavy irrigation to grow thirsty crops (paddy,

sugarcane), leading to water-logging and salinity, while tailends receive inadequate water, have lower intensities, grow drought-tolerant crops like bajra, and support a smaller population over less of the year than they might.

vi. timing: the staggering of cultivation

In this option, the timing of cultivation is staggered between different parts of a command. The costs and benefits of staggering can be complicated. Climatic conditions, photoperiod sensitivity of crops, and relationships of yield to temperature, sunlight, and rainfall at or near the time of harvest are all often relevant. There may be either wide or narrow latitude for planting dates for high yields. In the Dry zone of Sri Lanka, where involuntary staggering is almost universal in the growing of paddy in both the maha (main) and yala (subsidiary) seasons, there are also other advantages and disadvantages (for some of which see e.g. Chambers 1975:35-46)[4]. To some extent, staggering, where it occurs, is involuntary in that headreach farmers initially take quantities of water which leave little or nothing for the tails. This involuntary characteristic has tended to obscure its potential especially for productivity and equity. Two aspects may be mentioned.

First, staggering spreads peak water demands over different parts of the system. Especially in diversion systems where the river source limits peak flow, or where canal capacities constrain, this can mean that a larger area can be irrigated. Even with the warabandi of northwest India, it may be asked whether a larger area might not be irrigated by farmers through staggering the frequency of water deliveries (through the frequency with which minors receive water) in a phased manner throughout a command. Farmers might then stagger their planting dates, fitting their peak water requirements to those times when they would get water at closer intervals. As a result each farmer could then plant a larger area.

Second, staggering spreads peak power and labour demands. Labour shortages may well be a major constraint on medium and large farms in much of India's canal irrigation outside the Northwest: for example, Elumalai (1982:77) writes of the Parambikulam - Aliyar Project in Tamil Nadu that shortage of labour effects the full development of the command area even after a considerable gestation period. Labour is also probably a major constraint on large systems such as Malaprabaha and Tawa where there are many large farmers. With staggering, this constraint is eased, as labour moves physically down the command as cultivation activities succeed each other, with benefits not only to productivity, but also to the livelihoods of the labourers who gain longer periods of continuous employment.

vii. spatial and temporal cultivation rights

The final option is the spatial and/or temporal spread of cultivation rights. These are found in some traditional and other small or medium-scale systems. They involve equity either through the scattering of one family's holdings through several zones, one or more of which may receive water; or through a sequence of rights to cultivate the same piece of land. The former is found in the bethma system of Sri Lanka (Farmer 1957; Leach 1961), and in the phad system of Maharashtra (Patil 1981), and the latter in the kattimaru and thattumaru tenure of Sri Lanka under which the rights to cultivate a number of paddy plots are rotated annually among several people. While these systems are not very common, they are both productive and equitable: productive through the growing of the same crop in the whole of a block of land making it easier to supply appropriate water, and through matching the area to be irrigated to the amount of water available in each season; and equitable because where water is inadequate, all cultivators lose the chance to cultivate in those blocks which it is decided cannot receive water and all share in those blocks which are irrigated.

While this option may not be open on many large-scale systems, it deserves to be on the check-list for any lateral-thinking approach to irrigation planning and management.

Conflicts Between Objectives

This repertoire is far from a complete list but it does include some of the more obvious measures available for optimising the achievement of productivity, equity, stability, carrying capacity and well-being. These objectives, with any one set of measures, in any one context, may be complementary or may conflict. The greatest interest is attracted by conflicts and the choices which they present, but the greatest opportunities may be presented by complementarities. Let us, however, start with conflicts. For any five objectives, ten conflicts on a one-to-one basis are theoretically possible. With ingenuity or wide knowledge, examples of all ten might perhaps be mustered. But only four seem obvious to the writer:

i. productivity versus equity

Three common conflicts between productivity and equity can be suggested:

First, transmission losses. Between headworks and tailend fields transmission losses are often high, with figures of over 50 per cent. Other things being equal (which, however, they never are) this means that water available at the reservoir or diversion will be more productive at the head than at the tail; distributing water to the tail may then be more equitable, but distributing itto the head more productive. (This is simplistic, and some of the complicating and compensating factors are discussed below pp. xx - xx).

Second, water scarcity. When water available is less than that required for the crops that are growing, the equitable distribution of water over an entire system might mean low production or no production at all, whereas the inequitable concentration of the water in one area will be more productive, enabling a crop to be harvested at least there even if not elsewhere.

Third, groundwater 'mining'. If, as in parts of Tamil Nadu, there is a decline of the groundwater table in normal years

through 'overextraction', this may be offset by intermittent total recharge in years of very heavy rainfall. Productivity, in the sense of total production over a long period, may be higher with 'mining' in normal years, since this provides space underground for the storage of more water in years of very heavy rainfall. But equity will not be served to the extent that smaller and poorer farmers lose out. Some will be unable to deepen their wells as the water level drops and others unable to afford lift technologies which can raise water from greater depths[5].

ii. <u>productivity versus stability</u>

This conflict occurs where short-term productivity of land is at the cost of long-term. The most common example is where water applications in the headreaches are liberal, and used for thirsty crops like paddy, which are highly productive in the short term, but which lead to declining yields and even no yields at all through consequent rising water tables, waterlogging and salinity. Another example is groundwater mining where extraction exceeds recharge (even taking account of years of heavy rainfall), with the result that production eventually ceases.

iii. <u>well-being versus productivity</u>

A community may require canal water for domestic purpose during a dry season when there is no irrigation. This dry season flow depletes a storage reservoir so that less water is available for irrigation the next season, and less is produced.

iv. <u>well-being versus equity</u>

Continuing the example above, because less water is available in the next season, tailend supplies suffer.

Where there are conflicts, such as these, and where management interventions can affect them, then hard choices have to be made about the trade-offs. A useful technique for optimising is a transformation curve which plots the performance of different

measures against the two objectives which are represented by the x and y axes (see e.g. Major and Lenton 1979:190). But it can easily escape attention that the repertoire of measures for optimising is so extensive that it may always be worthwhile to search for complementarities, and only to accept choices involving straight conflicts (where more of one means less of another) when an inventive search for complementarities has failed.

The shortness of this list of conflicts may be the result of my ignorance and lack of imagination. Provisionally, it suggests that conflicts between these objectives are not all that serious or common (except perhaps with productivity versus equity) and that the complementarities between them are usually strong.

Complementarities

Setting the five objectives against the seven sets of measures in the repertoire (and bearing in mind that there are also many other measures, especially through improved structures, and on-farm development), there can be striking potential complementarities at system level between productivity of water, equity in its distribution, long-term stability, high carrying capacity, and well-being. For the sake of brevity, let us consider only one type of situation which is familiar in India outside the northwest.

Early in the life of a project, water is abudant because the headworks are complete but the canals and other works lower down are not yet ready. So the headreaches receive much water and grow paddy or sugarcane, the paddy often under more of less continuous flow and with field to field irrigation, even though high infiltration rates make some of the soils unsuitable for these crops. As construction is completed towards the tailends, not enough water is available for them because the head reaches continue to appropriate more than their designed requirement. Receiving less water, less reliably, and in a less timely fashion, farmers at the tails grow less profitable, drought-tolerant

drops, with lower intensities. And in consequence of heavy water applications at the head and the high infiltration rates, the water table rises and waterlogging, salinity and declining productivity ensure.

In such conditions, redistribution of water from head to tail can achieve all five objectives simultaneously. If less water is issued at the top, farmers there can grow crops which are more suitable for the soil, and if water is redistributed to the tails, then total production should rise, and equity will be served. Stability will be enhanced through reduced water-logging. Carrying capacity will be increased through higher labour demand both in the head reaches (to the extent that dry crops are more labour-demand than wet, and that intensities are higher), and in the tail where irrigated area and intensities increase. Well-being should gain through these effects, through reduced health hazards from standing water in the head reaches, and through more canal water for domestic purposes in the tails.

The main qualification is the possible conflict of productivity and equity if transmission losses are high between the head and the tail. The problem is not the equity, since tailenders are receiving more water, but the total productivity of the water available to the system. Adverse effects of the transmission losses can, however, be exceeded by production gains of two sorts:

i. groundwater recharge from seepage in transmission. Though a problem in the headreaches, elsewhere this can be a benefit, providing groundwater closer to the surface both for conjunctive use in irrigation and for domestic purposes. A problem in the headreaches thus becomes an opportunity lower down. Groundwater reduces risks, raises cropping intensities. Moreover, farmers who have to lift irrigation water tend to use it more sparingly and productively than those who receive it through surface channels.

ii. higher productivity of water, after allowing for transmission losses, at the tail, resulting from larger areas irrigated, water-sparing crops, and the adoption of higher-yielding practices in response to a more adequate, convenient, predictable and timely water supply.

Given these major advantages of redistribution, the question is what prevents their realisation.

Practical Political Economy

There are many physical and technical impediments, but many constraints also appear to lie in the political economy of canal irrigation. Those who gain from current management practices may lose from changes. The approach of practical political economy is then to ask who would gain and who would lose and to see a. whether there are ways in which the repertoire could be used to enable all to gain from the changes, and b. if that is not possible, whether there are ways in which inevitable losers could be reconciled to their losses.

Three sets of problems and opportunities may especially deserve analysis. They are: the professional training and incentives of irrigation managers; the search for the non-zero sum, for ways in which topenders can gain from receiving less water; and the purchase and distribution of land.

i. the professional training and incentives of irrigation managers

Perhaps the greatest problem in improving canal irrigation management lies in the professional training and incentives of irrigation managers. The emphasis of training on design and construction is well known, and there are moves in the direction of developing training for operation. But one difficulty is that the very methods of diagnostic analysis, of monitoring and control, of water scheduling, of managing staff and farmers, and of training itself - are in early stages of development for South Asian conditions. The International Programme

for Irrigation Management[6] when it is finally launched and if it holds to the objectives set for it, should contribute to these methodologies and to training which can spread knowledge and use of them; initiatives like the course for irrigation managers at the Indian Institute of Management, Bangalore, should break new ground in developing materials and methods; and the Indian Government has major proposals for training.

But even if the professional training in canal irrigation operation were already available, there remain the problems of personal incentives for irrigation managers to manage systems so as to optimise the five objectives. Caution is needed in generalising, and the warabandi systems of Northwest India may be exceptions to what follows. But careful, scholarly studies have documented aspects the working environment of irrigation managers which suggest that they are subject to incentives to manage their systems badly. Pant (1981:102) records some of the grievances of farmers on the Kosi canal as follows:

> 'Unlimited amount of water was given to certain farmers, irrespective of the location of their fields, who obliged officials in terms of money or grain. In case of others, they would charge money but would never bother to know whether water was made available to them or not. With regard to canal maintenance, the feeling was that overseers and engineers were not interested in the upkeep of canals. Every year vast amount was spent on the repair of canals but they remained as before. The main reason was, that the officials were interested only in getting their 'shares' from the contractors and never bothered whether the work was properly done or not by the contractors.'

For another part of India, Wade (1982) confirms this impression and elaborates on a system of control of transfers, sale of posts by politicians to engineers, channelling of funds through contractors, and earning by engineers of many times their annual salaries from maintenance works and from farmers.

To the extent that such systems prevail, incentives are perverse and low standards of management and maintenance of canals,

otherwise so puzzling with able managers, are less difficult to understand. They have a need to raise money to buy their postings, which can cost as much as ten times the annual salary of the officer (Bhargava 1982), and to be able to stay in them, and they have the opportunity to raise money for themselves; but this is at the cost of stability - of maintenance that is not carried out or which is sub-standard, and at the cost of productivity and equity in the distribution of water since managers have an interest in not communicating with farmers, in 'rumour-mongering' about water shortages, in engendering uncertainty, and in delaying deliveries.

In the context of this paper, the issue is not a moral one. It is the straight practical question of how, where such conditions occur, it can be made rational for managers to change their practices. Apart from changes in the wider political system, several suggestions have been made (Wade 1982:320-1), of which the three strongest may be professional training, to include not only engineering and agronomy but also management science, and which should aim to foster the development of an ethos of professional service around operation and maintenance; the provision of storage intermediate between dam and fields so that irrigators would have more control over their water supply; and strengthening the user side both by councils of irrigators and through an independent monitoring organisation, the reports of which would be made public.

ii. the search for ways all can gain

With redistribution of water from headreaches towards the tails, it may appear that farmers in the headreaches must lose, and therefore oppose the change, but this is not necessarily so. In the classic and much cited case of the Lateral C on the Penarauda River Irrigation System in the Philippines, tighter management and redistribution of water led to higher yields for all locations (Wickham and Valera 1978).

Quite often, headreach farmers appear to be locked in to their variety of the tragedy of the commons. This is especially marked with field to field irrigation of paddy. The abundant issue of water and consequent flooding, combined with the cultivation of paddy by his neighbours, remove any option from a farmer to grow anything but paddy; and then because all farmers follow this practice, water-logging, salinity and flooding ensue, reducing or eliminating yields.

But with a change of water issues to a smaller but more controlled, convenient, predictable and timely supply, together where necessary with on-farm development (field channels, bunding, etc.), top-end farmers may be able to gain from less water in the following ways:

- less waterlogging and salinity
- less damage from flooding
- less leaching of nutrients
- better returns to fertiliser and other input applications
- more varied and flexible cropping patterns, responding to demand and prices
- timely water for crop requirements
- higher cropping intensity, especially if some of the water saved (by switching from paddy and by restraining water issues at times of heavy rainfall) can be stored to support an additional crop (for example in South India by changing from one Irrigated Wet crop to two Irrigated Dry crops, as preferred by some farmers (Wade 1978)
- more convenient scheduling of farm operations through knowing when water will come (and release of time in between waterings for other activities)

In short, the possibility is of enhancing the productivity of water and other factors such as land and labour through trading off less water with other characteristics of water supply such as fit in time and quantity with crop water requirements, manageability, and predictability.

Not enough is known about the opportunities here, but an example from Sri Lanka is encouraging. After a field trip to the Kaudulla Project in the Dry Zone of Sri Lanka, M.P. Moore (1980) wrote:

> '..the I.E. (Irrigation Engineer) wanted to give water for paddy to stage I (presumably in the head reach). The farmers responded with the request for water for highland crops for the whole scheme. Even stage I farmers supported this strong evidence that the higher prices of non-paddy food crops are weaning farmers away from their devotion to rice'.

In this instance, at the insistence of farmers against the irrigation management, both productivity and equity were, it seems, likely to be served by redistribution to other parts of the project of water that would otherwise have all gone to the top.

Perhaps there is, over much headreach land in India, what might be described as a latent ratchet: a possibility of a collective change to a more productive, more profitable and more water-sparing farming system which is prevented because seepage, flooding and field-to-field irrigation lock farmers in to paddy. On large canals, the collective decision-making of smaller systems in Sri Lanka may be difficult. But a priority would seem to be to develop and use methods of farming system analysis which can identify potentially preferable cropping patterns, to try these on limited areas, and then to promote collective decisions to change.

If analysis shows that topenders must lose, the issue is then political, and the most effective solution will be political, through providing means for tailenders to apply pressures and to negotiate redistribution.

iii. <u>purchase and distribution of land, or 'redistribution when growth'</u>

A massive opportunity for all to be better off than before is presented by the redistribution of land at the time when new

irrigation is introduced. At that time, the land of farmers who will receive irrigation water is 'stretched': it is likely to have potential to produce more, to have a higher cropping intensity and decreased risk, and to double or treble or more in value. These are windfall gains. If, at the time these gains were occurring, land were bought from larger farmers and made available to very small farmers and to the landless, larger landowners could still end up much better off than they were before irrigation came. In some other versions of land reform, larger farmers are bound to end worse off. In this version, they might or might not be better off than they would have been without the reform, depending on the prices paid for the land, but they would be better off than they were before. Opposition to the programme, and subversion of it, might then be less marked.

Redistribution 'when' growth is far from a novel suggestion. The land ceiling legislation in most Indian States differentiates between a higher ceiling for rainfed and a lower ceiling for irrigated land, implying that redistribution should take place when irrigation arrives. The opportunities presented have also been pointed out for lift irrigation by B.G. Verghese, for tank irrigation by A. Sundar and P.S. Rao, and for canal irrigation by Anthony Bottrall.

In an article on lift irrigation introduced by the Deen Dayal Research Institute in Gonda District, in eastern Uttar Pradesh, Verghese (1981) speculates as follows:

> 'It might also be feasible to appeal to those whose farm sizes have been irrigationally 'stretched' twofold or threefold to donate a small fraction of the 'land gain' to a common pool which, if consolidated could result in the creation of a land bank of five, 10 or more acres in a village in a new variant of bhoodan in which benefited individuals gift land to the community of which they are a part and on which crops or kitchen gardens could be cultivated by young farmers' clubs or hired labour for village school-feeding programmes, or fodder raised for landless dairy farmers, or fuel trees, or whatever....'

In a paper on land acquisition for minor irrigation tanks, Sundar and Rao (1981) observe that those whose land is acquired for new minor irrigation tanks lose out: either they are allocated land which is often not as good as that which they lost, or they are compensated inadequately and late in cash. In contrast, those within the command of the tank gain from the higher productivity and enhanced value of their land so that the effective holding after the completion of the project is twice or more that of the pre-project stage. If a small portion ofthe land of farmers in the command were purchased from them with the money that would otherwise have gone on compensation to those who lose their land to the tank, and if that purchased land were allocated to the evacuees, everyone would be better off than before.

For canal irrigation, Bottrall (1981:28) considers that there are "very good opportunities for land redistribution of the initial planning stage, before project completion". Indeed, if we examine the figures for India, the potential equity benefits for very small farmers and the landless of any effective programme of purchase and distribution of land when irrigation is introduced appear quite staggering. Table 1 gives the existing and ultimate irrigation potential in India:

Table 1

Existing and Ultimate Irrigation Potential, India
(million hectares)

	Surface Irrigation			
	Major and Medium	Minor	Groundwater	Total
Ultimate	58.5	15.0	40.0	113.5
1981/82(estimate)	28.6	8.4	24.5	61.5
Potential still to be realised	29.9	6.6	15.5	52.0

Sources: 1. Report of the Irrigation Commission, 1972.
2. Report of the National Commission on Agriculture.
3. Ministry of Agriculture and Irrigation, Central Water Commission and Central Groundwater Board.

See also GOI 1982:59.

The Sixth Five-Year Plan envisages creating the remaining potential by the year 2000. To get a sense of orders of magnitude, let us suppose that with shortfalls in target achievement, some 40 million hectares are added by the end of the century. If only one quarter of that land was purchased, 10 million hectares would become available. If landless families were settled on one irrigated hectare each, this could mean that some 10 million households, drawn from the poorest, would become irrigation farmers, directly supporting perhaps 50 million people, and indirectly supporting many more in secondary employment.

Gains in productivity could also be expected through the inverse relationship: the areas retained by larger farmers would be more productive per unit area by virtue of becoming somewhat smaller; and the new small farms should, partly because of their manageable size, be highly productive per unit area.

The difficulties of redistributive land reform are well known.[7] With redistribution <u>when</u> growth takes place through new irrigation, and with prompt compensation, there would be three points which suggest that the process might be politically more feasible:

i. the farmers who sold land should find cash useful at the time when irrigation came. The exploitation of irrigation water usually requires further investment - in land shaping and levelling, in the construction of channels and drains, in the purchase of inputs, and in the employment of labour.

ii. the farmers who sold land would be left with a more manageable unit.[8] With irrigation, the management of a farm becomes much more demanding. Farmers who sold land might often find the new smaller farm easier to manage, and might even achieve a higher net income off that smaller farm, well capitalised, than off a larger area of land which was more difficult to manage and under capitalised, and which might otherwise be left fallow or cropped at a low intensity.

iii. in planning new projects with smaller rather than larger areas under command to allow higher intensities of irrigation. This would require careful appraisal, scheme by scheme. Especially where water can be carried over from season to season in storage, a smaller area covered by the 'membrane', but which was covered by it (i.e. cropped) more often during the year, could, when combined with land redistribution, be more productive and more equitable. In this case, the larger farmers some of whose land was taken, would additionally gain through the higher intensities and the size of landholing that was viable for the newly settled farmers might be reduced, thus enabling more to be settled.

The crucial question is whether a programme of 'redistribution with growth' could be administered. The key aspects are the values set on land, and prompt payment.

First, high enough prices. If purchase prices were set too low, it might look good in the accounts, but it would aggravate the dangers of the process being subverted. An emphasis on 'purchase' rather than 'compensation' would require prices higher than the pre-irrigation land values, but in terms of families subsequently settled this might be cheap at the price.

Second, prompt payment. Many schemes have fallen down because of long delays in payment.[9] Acceptance of a programme of land purchase would be much easier with cash on the nail.

For both these reasons, purchase of land would be best undertaken in advance of the arrival of irrigation-because land prices would be lower, and because cash payments would be in time to allow larger farmers to invest in land improvement.

A practical difficulty is that these activities would coincide with other urgent and demanding work on the official side. With canal irrigation, these include dam and canal construction, the distribution of the first water, extension activities for changed agriculture, and on-farm development below the outlets.

Staff for land acquisition are liable to be engaged in obtaining land for canals and other works. A programme of 'redistribution when growth' would require a greater concentration of staff effort at an early stage, and perhaps a special section or department.

Conclusion

To proceed further with some of the practical questions in this paper, would seem to entail, among others, the following next steps:

i. field testing and development of operational criteria such as productivity and equity

ii. analysis of alternatives in water scheduling, and how to determine optimal schedules. A textbook on this would appear a high priority, but the methods of analysis and scheduling have to be developed and systematised first.

iii. the development, dissemination and use of methods of cost-effective farming systems analysis to identify how headreach farmers can benefit from less water

iv. assessment of the potential for land redistribution through purchase from larger farmers at the time when irrigation comes, including a reassessment of current land ceiling practices. This would again include farming systems work to determine appropriate farm sizes for those who were settled on the purchased land.

Acknowledgement: I am grateful to Roberto Lenton for useful comments on an earlier version of this paper as a result of which I have made several corrections and improvements. The views expressed are mine and do not necessarily reflect those of the Ford Foundation.

Notes and References

1. Productivity is defined in Bannock,'Baxter and Rees' A Dictionary of Economics (Penguin 1972) as 'The 'productiveness' of a factor of production measured by expressing output as a ratio to the amount of input required to produce it; or by expressing the change in output as a ratio to the change in amount of input required to bring it about'. I am using productivity in the first of these two senses.

2. Water and Power Consultancy Services (I)Ltd., "Kailash", 26 Kasturba Gandhi Marg, New Delhi 110 001.

3. I would like to be proved wrong and would welcome references to sources apart from those cited in this paper, where these aspects of irrigation management are considered together.

4. There is a substantial subsequent literature derived from research by the Agrarian Research and Training Institute, Colombo, and Reading University.

5. There is an interesting analogy with strategies in pastoralism on common land. An earlier theory had it that a constant level of stocking should be aimed at, the objective being sustained production at a safe and rather low level. This has now been challenged with a theory that range will be more productive if stocks are allowed to increase in good years beyond what was previously considered a safe level, recognising that heavy destocking would be necessary when bad years come. The conflict with equity arises because those with few stock are less well able to build up herds in good years, and are more vulnerable to losing stock or being unable to sell them, in bad years.

6. The International Programme for Irrigation Management has emerged from discussions and explorations within the Consultative Group for International Agricultural Research, the Technical Advisory Committee of which set up a Study Team recommended priority to developing methodologies, together with training, selective information dissemination, and action research. The CGIAR endorsed the proposals as the highest next priority but budget cuts prevented its undertaking direct financial responsibility. A group of interested donors has asked the Ford Foundation to be the lead agency in taking the next steps in establishing the Programme.

7. I have written this without reviewing the experience with the operation of the land ceiling differential between irrigated and rainfed land. The reader is asked to bear in mind that for that reason some of the comments and suggestions may be misplaced, or may even be current practice.

8. This is, I think, a valid argument, but it must be qualified by recognising the frequency with which farmers tackle the problem of too much land to manage by leasing it out either for rent or with sharecropping arrangements.

9. In Sri Lanka, in the H area on the Mahaweli Project, compensation was meant to be paid to farmers who lost land above a certain acreage; but when it was not assessed and seemed unlikely to be paid, unofficial compensation took place in the issuance of additional plots to the larger farmers, thus reducing the numbers of landless households that could be settled.

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3

A NOTE ON MONITORING PRODUCTIVITY AND EQUITY IN IRRIGATION SYSTEMS

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The purpose of this note is to outline some practical and operational methods to monitor the extent to which large-scale irrigation systems achieve productivity and equity objectives. Emphasis will be on defining the minimal amount of information necessary to properly estimate the performance of an irrigation system in these terms, and to enable irrigation system managers to determine whether the irrigation system is performing correctly or not. As we shall see, even simple measures of performance require extensive measurement. For this reason, care should be exercised to limit the amount of data required to a minimum, in order to make it possible to operationalize performance monitoring for large-scale irrigation systems.

In this note, I will use the word "productivity" in its more general sense to denote the output of a development project, and "equity" to refer to the quality of the distribution of that output. In particular, I will focus on two measures of the "productivity" of an irrigation system, and one measure of "equity", and attempt to sketch possible ways to monitor these performance criteria for large-scale irrigation systems. The productivity measures are :

1. Water delivery : quantity and timing of water delivered to farms
2. Crop yield from irrigated land.

The first of the above indices can be said to define the performance of an irrigation system, whereas the second defines the performance of the agricultural system associated with an irrigation project (Seckler, 1981 b).

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Three desirable characteristics of performance criteria for irrigation systems management are (1) that they be measurable for large-scale irrigation systems; (2) that they be measured against performance standards; and (3) that they be normalized between 0 and 1 (performance equals 1 when the irrigation system meets performance standards perfectly, and zero when it completely fails to do so).

In defining performance standards, I will adopt a "dynamic" approach, in which actual performance is measured against potential performance given current operating conditions and knowledge of design parameters. If performance is measured against this "updated" potential performance, it is possible to take maximum advantage of existing opportunities for improving irrigation performance, and adequate consideration of new constraints which might impede performance.

Productivity Measures

Before discussing the productivity measures in greater detail, a discussion of the measurement of performance in terms of actual area irrigated is in order. This method of performance monitoring is a well established practice in India, where figures for "irrigation utilization", measured against "irrigation potential", are routinely compiled by Irrigation Departments. However, this procedure is far from satisfactory. It doesn't distinguish, for example, between areas that are adequately irrigated and those that are not; "irrigated" could mean anything between one poor irrigation and several adequate and timely irrigations. Furthermore, the way in which irrigation utilization and potential are defined and monitored in practice makes the concept virtually meaningless, as is forcefully brought out in the report by the Central Water Commission's Committee on "Rationalization of Statistics and Methods of Assessment of Irrigation Potential and Utilization" (CWC, 1981). For this reason, in this note I will concentrate on water delivery and yields, which in my opinion are more appropriate indices of the productivity of an irrigation or irrigated agricultural system.

Productivity Measures

Water Delivery

Although water delivery is undoubtedly the most complete indicator of the performance of an irrigation system, it is very seldom monitored, even in research studies designed to analyze measures to improve irrigation management. This is perhaps understandable in view of the inherent difficulties of both definition and measurement. Nevertheless, as we shall see, these methodological difficulties are not insurmountable, and it is unquestionaly possible to establish programs to monitor water delivery performance over large areas at a reasonable cost.

With water delivery performance, as with yields, the general approach I will follow in this note will be to define criteria at the individual farm level, and then proceed up the system, at higher and higher levels of aggregation, in order to define performance criteria appropriate for the outlet, minor, distributory, branch, and system level. I will describe these definitions in some detail, so that the complexity of monitoring performance at high levels of aggregation may be fully perceived.

Using the notation indicated in Figure 1, one appropriate measure of water delivery performance (WDP) to take into account the quantity and timing of water delivered to a farm could be defined as follows :

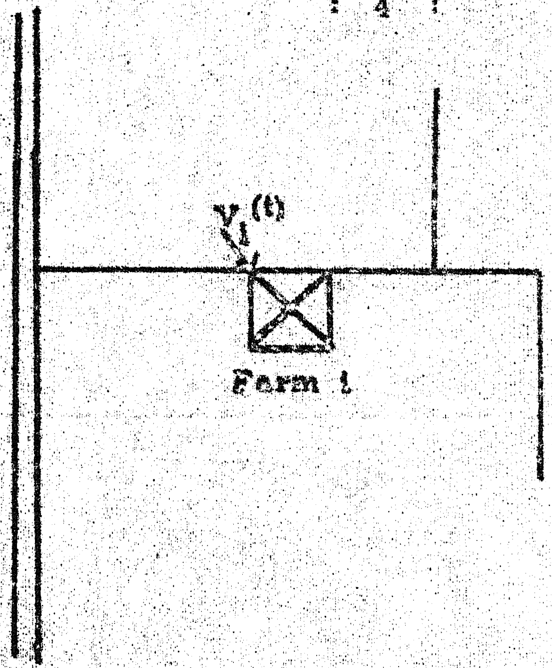
$$WDP_i = \sum_{t=1}^{n} \frac{k(t)\ V_i\ (t)}{V_i^*\ (t)}\ ; \qquad V_i\ (t) \leqslant V_i^*\ (t)$$

$$\sum_{t=1}^{n} k(t) = 1$$

where

$V_i\ (t)$ = Volume of water delivered to farm i during week (or other time period) t of cropping season.

$V_i^*\ (t)$ = Target volume of water to be delivered to farm i during week t of cropping season, calculated for actual crops grown and existing conditions of soil, rainfall, and other sources of water.



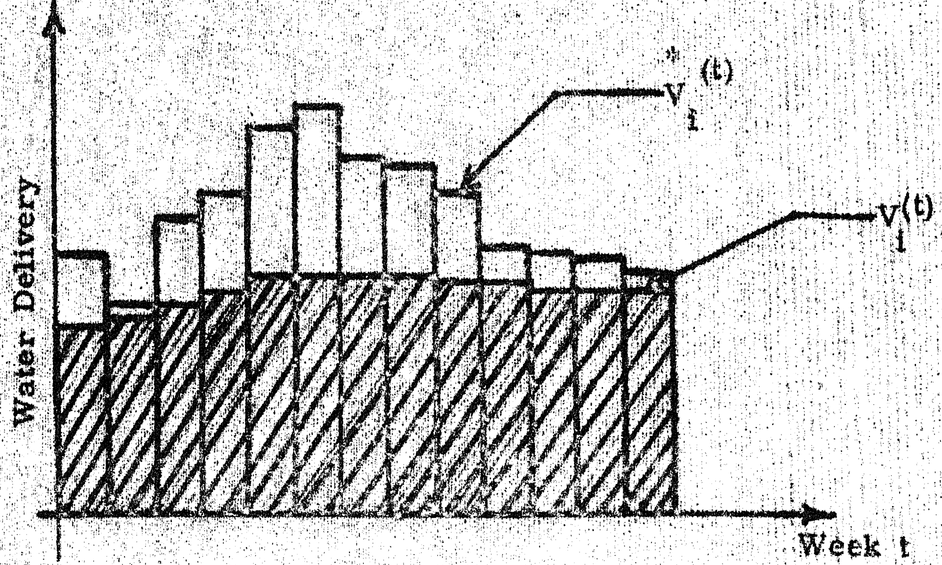


Figure 1. Water Delivery to the Farm

$k(t)$ = Weighting factor indicating the relative importance of water at different stages of crop growth.

n = Number of weeks in cropping season.

With water delivery performance defined in this way, WDP_i would equal one if the water delivered to the farm during each week of the cropping season is equal to the target water delivery, and zero if water is never delivered during any of the weeks of the cropping season. If water is delivered at the wrong times and/or in the wrong amounts, water delivery performance will vary between 0 and 1.

I should note that several alternative definitions of water delivery performance might be possible. One modification would be to use a multiplicative function rather than an additive function. If WDP is defined in this manner, there should be a strong correlation with yield, since most functional relationships between yield and water delivery (other inputs being held constant) are defined in approximately this way. (Thus, if the data do not show strong correlation between WDP and yield, one might conclude that there are large differences in input use between farms). Another modification would be to explicitly account for the harmful effects of over-irrigation, perhaps by using :

$$WDP_i = \sum_{t=1}^{n} \xi_i(t)$$

where

$$\xi_i(t) = \begin{cases} k(t) \dfrac{V_i(t)}{V_i^*(t)} & \text{if} \quad V_i(t) \leq V_i^*(t) \\[2ex] k(t) \dfrac{V_i^*(t)}{V_i(t)} & \text{if} \quad V_i(t) > V_i^*(t) \end{cases}$$

(WDP_i as defined earlier assumes that if water delivered is greater than target water delivery, water delivery performance is not affected).

Yield

Yields are relatively easy to measure and the methodological difficulties involved in monitoring yields are few. Perhaps for this reason, monitoring of crop yield is routinely done in both rainfed and irrigated areas in India and other countries of the region. Nevertheless, such data is usually collected on a block or district level basis, and there are not many examples of measurement of crop yields as an integral component of the performance monitoring of an entire irrigation system. The few outstanding examples include a program implemented by WAPCOS, which I will describe in a later section, and a program implemented by the National Irrigation Administration of the Philippines on the Upper Pampanga River (see Republic of the Philippines, 1980).

The most straightforward way of defining a normalized indicator of yield performance is :

$$YP_i = \frac{Y_i}{Y_i^*}$$

where

YP_i = Yield performance on farm i

Y_i = Total yield for crop grown in farm i

Y_i^* = Target yield (for example, yield obtainable in farm i given optimum irrigation and existing levels of inputs).

This definition is useful for those areas (or seasons) where only one crop is grown - for example, irrigation during kharif in many parts of India, where paddy is the dominant crop. It would not hold for most irrigation projects during the rabi season. Where more than one type of crop is grown, a more valid indicator of yield performance might be total farm output, defined in terms of total crop values (sum of individual crop yields multiplied by price).

The above definitions of water delivery and yield performance require the measurement of several variables. Irrigated area and yield are comparatively easy to measure. Perhaps the most

difficult variable to measure is $V_i(t)$, the actual volume of water delivered during a given week of the cropping season to the farm. In order to estimate actual water delivery, it is necessary to measure both the flow rate of water delivered to the farm, and the total amount of time that the farm receives water during the week. Since measurement of flow under field conditions at the farm level can be complex (see Bhuiyan, 1981), one simple possibility would be to measure the length of time a farm receives flow, and the area irrigated during that time, under the assumption that all farmers irrigate a given area to the same irrigation depth (Seckler, 1981). Of course, estimating water delivery to a farm is simpler in rotational water supply systems, than it is in continuous supply systems (e.g. warabandi in North India), since in the former case the date and time during which a farmer is due to receive water is known in advance, and the project monitors can simply verify that the farm is receiving water according to the known schedule.

In addition to estimating actual water delivery and crop outputs, the above performance criteria require the estimation of performance standards, including $V_i^*(t)$ and Y_i^*. These should be interpreted as target levels of performance established by management. For example, $V_i^*(t)$ should not necessarily be equal to the water requirement of the irrigated crops. If management has a policy of extensive rather than intensive irrigation, the target volume of water delivered to the farm could be substantially less than crop water requirements, in order to maximize total production and area. Irrigation systems in Haryana, for example, are designed and operated so that each farmer receives water to meet crop water requirements in at most one-third of the farm area.

System Level Definitions and Sampling

The above are farm-level definitions of water delivery and yield performance. In order to estimate performance at the outlet (or minor, distributory, branch, and system level), we need to determine similar definitions at higher levels of aggregation. Figure 2

illustrates the estimation of water delivery performance at the outlet level. Defining water delivery performance at the outlet level as the average water delivery performance at each of the individual farms commanded by the outlet, we obtain :

$$WDP = \frac{1}{N} \sum_{i=1}^{N} WDP_i$$

where

WDP = water delivery performance at the outlet

N = Total number of farms in the outlet

WDP_i = Water delivery performance at farm i (if farm i does not receive water, WDP_i equals 0).

Figure 3 illustrates the way in which expressions for water delivery performance at the minor, distributary, branch, and system level may be defined. For example, water delivery performance for minor k may be written

$$WDP_k = \frac{1}{N_k} \sum_{j=1}^{N_k} WDP_j$$

where WDP_j = Water delivery performance at outlet j

N_k = Number of outlets along minor k

Although the above equations appear to imply the need to measure water delivery performance in each individual farm within the irrigation system, in fact this is not required. Rather than measure water delivery performance in each individual farm, data collection can become far more manageable by sampling individual farms within the system. For example, water delivery performance at the outlet may be estimated by the "sample average", as follows :

$$\widehat{WDP} = \frac{1}{N_s} \sum_{i=1}^{N_s} WDP_i$$

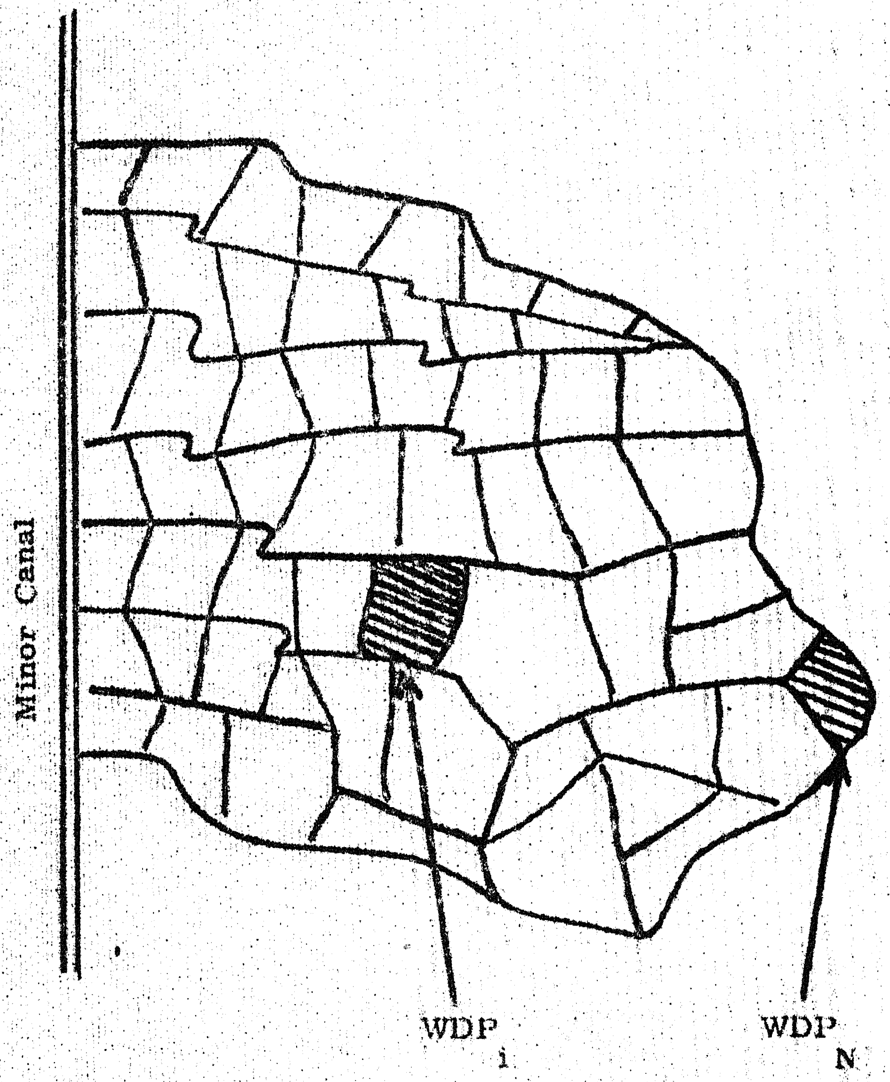


Figure 2. Water Delivery Performance at the Outlet Level

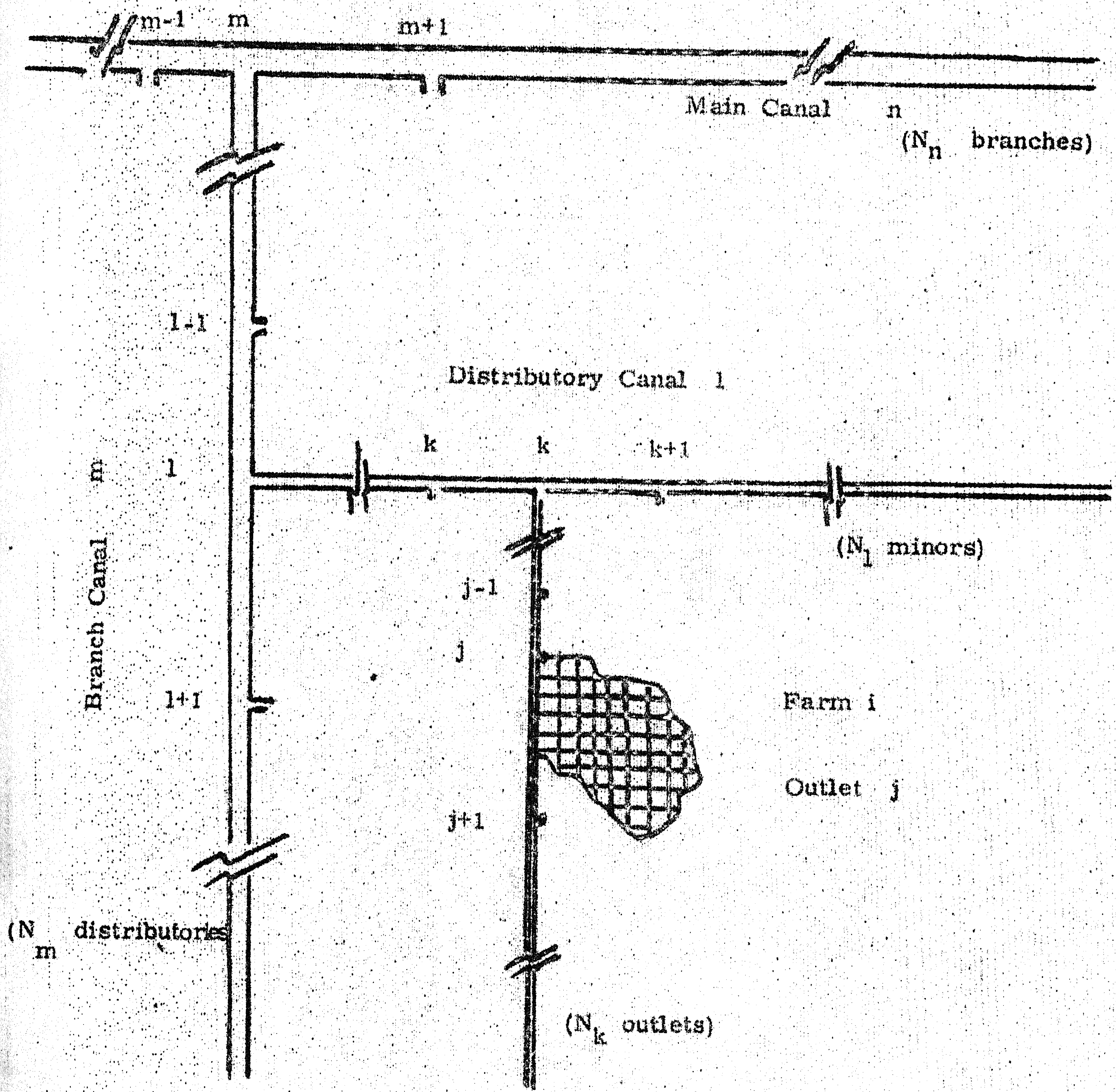


Figure 3. System Level Definitions of Water Delivery Performance.

where

WDP = Estimate of water delivery performance at the outlet (sample average).

WDP_i = WDP measured at the i^{th} sample farm.

N_s = Total number of farms sampled within the outlet.

Statistical theory can then be utilized to define confidence intervals for these estimates of delivery performance.

At the minor canal level, WDP_k can be estimated by sampling N_{ks} outlets :

$$\hat{WDP}_k = \frac{1}{N_{ks}} \sum_{j=1}^{N_{ks}} \hat{WDP}_j$$

where

$\hat{WDP}_j$ = Water delivery performance at j^{th} sample outlet.

Similar definitions can be found for estimating performance of distributory 1, branch m, and the entire irrigation system.

Equity Measures

The definition of equity in an irrigation system has often been a subject of much debate. In my opinion, the clearest way to define equity is in terms of the variability of water delivery or yields between individual farms located within the command of an outlet or minor, distributory, branch or main canal system. I will illustrate the concept by defining variability in water delivery at the outlet level, and then generalize to definitions at higher levels of aggregation.

Variability in water delivery within an outlet can be measured in several ways. One way, which would account specifically for the variability caused by farm distance from the head of the outlet, would be to measure the ratio between the performance of a farm at the head of the outlet (WDP_t) and performance at a farm at the tail of the outlet (WDP_h). Equity of water delivery (EWD) could thus be defined as :

$$EWD = \frac{WDP_t}{WDP_h}$$

The above definition focuses only on performance at two extreme locations within an outlet. An alternative definition would be the range, i.e. the difference between the maximum and minimum values of performance for all farms in the outlet. Normalizing to obtain a value between zero and one, EWD would be defined by :

$$EWD = \frac{WDP_{min}}{WDP_{max}}$$

where

$$WDP_{max} = Max \left\{ WDP_1, WDP_2, \ldots, WDP_N \right\}$$

$$WDP_{min} = Min \left\{ WDP_1, WDP_2, \ldots, WDP_n \right\}$$

In practice, water delivery could be monitored at N_s sample farms within the outlet, and variability measured by the "sample range" obtained from the N_s sample values. However, the use of the sample range suffers from several deficiencies, including that it is very sensitive to the number of observations of performance made within the area, and particularly to the extremes. A more appropriate measure of variability is the variance in water delivery performance :

$$\sigma^2 = \frac{1}{N} \sum_{i=1}^{N} (WDP_i - \overline{WDP})^2$$

The variance in water delivery performance can be measured in practice through the sample variance s^2. A practical definition of equity of water delivery would then be :*

$$EWD = 1 - \frac{s}{\overline{WDP}}$$

Definition of variability delivery performance at higher levels of the system can be illustrated with the help of Figure 3. At

* Note that in this case EWD is not necessarily greater than zero.

the minor level, for example, two levels of variability are important : one, the variability in performance among all the outlets located along the minor; the other, the variability in performance among all the farms located in the command area of the minor. Using head/tail variability for the sake of simplicity, we can write :

$$\text{Minor/Outlet Variability}_k = \frac{WDP_{j = t}}{WDP_{j = h}}$$

and

$$\text{Minor/Farm Variability} = \frac{WDP\ (_j = t;\ i = t)}{WDP\ (_j = h;\ i = h)}$$

At the distributory level, there are three levels of variability - distributory/minor, distributory/outlet, and distributory/farm - and at the branch and main systems levels, there are four and five levels of variability, respectively. Similar definitions hold, although from a practical point of view it is likely that only two levels of variability (that with respect to the next lowest order and canal, and that with respect to the farm) will be of interest.

Example : Monitoring of the Mahanadi Reservoir Project, Orissa

The above monitoring concepts are well illustrated by an excellent program to monitor yields within an irrigation system which was conducted by Water and Power Consultancy Services (India) Limited during kharif 1980 on two irrigation systems in Madhya Pradesh (see WAPCOS, 1981 a). These were the Mahanadi Reservoir Project, which irrigates 180,000 ha., and the Hasdeo-Bango Project (41,000 ha.). The program was undertaken by monitoring a large number of farms distributed within the irrigation system, and selecting heads, middles and tails both within outlets and along canals. The amount of

water received by the farms was not measured, making the estimation of water delivery performance impossible, but yields were assessed by crop-cutting experiments. The resulting farm yield estimates (for the Mahanadi Reservoir Project alone) are shown in Table 1 (WAPCOS, 1981 b).

Note : The views expressed in this note are the author's and do not necessarily reflect those of the Ford Foundation. The note draws heavily on material presented by the author at a special course on water management in irrigation systems held at the Central Water Commission in January 1982.

Table 1 : Field Data From M.R. Project*

Dy. Position on Canal	Minor Position on Dy.	Outlet Position on Minor	Farm Position on Outlet	Farm Yield	Av. Yield of Outlet	Av. Yield of Minor	Av. Yield of Distributory
1	2	3	4	5	6	7	8
		H	H M T	1935 1027 1661	1541		
	H	M	H M T	1212 1261 627	1033	1278	
		T	H M T	1259 1262 1261	1260		
		H	H M T	1027 875 1043	982		
H	M	M	H M T	1032 761 762	852	885	981
		T	H M T	844 728 895	822		
		H	H M T	898 1017 704	873		
	T	M	H M T	683 853 693	743	780	
		T	H M T	957 675 542	725		

Table 1 (contd.)

1	2	3	4	5	6	7	8
		H	H M T	498 930 426	618		
	H	M	H M T	1172 1438 1012	1207	842	
		T	H M T	1021 445 636	701		
		H	H M T	411 483 911	602		
M	M	M	H M T	NA NA NA	NA NA NA	602	780
		T	H M T	NA NA NA	NA NA NA		
		H	H M T	978 791 853	874		
	T	M	H M T	1121 671 967	920	897	
		T	H M T	NA NA NA	NA NA NA		

Table 1 (contd.)

1	2	3	4	5	6	7	8
		H	H M T	942 1529 1971	1481		
	H	M	H M T	616 622 977	738	882	
		T	H M T	313 714 250	426		
		H	H M T	1229 745 503	856		
T	M	M	H M T	439 641 294	458	480	
		T	H M T	72 251 59	127		562
		H	H M T	750 111 532	564		
	T	M	H M T	313 146 110	190	324	
		T	H M T	181 122 350	218		

* From WAPCOS, 1981 b.

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4

PERFORMANCE MONITORING IN LARGE SCALE IRRIGATION SYSTEMS

S.P. Malhotra, S.K. Raheja and David Seckler

Part I

Technical Programme of the Survey

The Warabandi system of management and distribution of canal water for irrigation to cultivators in a specified region has been in operation in different parts of the country for a number of years now. The main features of the system are :

i. Determining the time required for irrigating one acre of land with one cubic foot per second (cusec) of water discharge;

ii. Determining the amount of water needed (cusecs) for the total irrigable area or the culturable command area (CCA) in the specified region (generally known as a chak); and

iii. Allocating the time to different cultivators in rotation to be completed in a specified period (generally a chak) in a manner that all cultivators get water in proportion to their CCA in this period.

Water is an essential input and has to be made available to the crop at crucial stages of crop growth for obtaining assured yield level. However, the amount of water available is generally short of the demand and accordingly, the Warabandi system has to be designed and implemented very carefully to ensure equitable distribution of water proportionate to the culturable command area with different farmers.

Under the roster system of distribution of water according to a time schedule in the specified period, a cultivator gets water only during his fixed time allocation. He is thus assured of

the water supply at given intervals of time provided water is available in the canal. This is the chief merit of the system in so far as the system becomes self-policing without any external force or agency required to regulate and supervise the water supply at the outlet. The system has legal sanctity and support and any breach of time allocation system or unauthorized drawal of water is viewed seriously. On the other hand this is also the chief demerit of the system since a cultivator gets water only once according to his time allocation in the entire rotation period and has to make do with the same irrespective of the stage of the crop. It may thus happen that water becomes available when it is not required by the crop and not available when the crop badly needs it.

Another factor which may be important in the amount of irrigation water becoming available to a chak is the location of the chak or, in other words, the distance of the chak from the head of the canal or distributory. Although for a given level of water in the canal, the water supply to a chak is regulated through suitably calibrated and properly constructed outlet which releases a pre-determined amount of water, the actual level of water in the canal at the outlet might vary even from day to day because of various reasons like leakage or breach in the canal, defective or damaged outlets, etc. in the upper part of the canal. Thus, the greater the distance of the chak from the head, the greater is the possibility of the fluctuations in the water level in the canal which will affect the water supply to the chak. The distance of the chak from the head would thus be a crucial factor in the actual supply of water to a chak and may have to be taken into account appropriately.

Similarly, within a chak, a field may be located near or away from the outlet, i.e., at the head or middle or tail of the water course. Although the Warabandi system is so designed as to take into account the time required for filling of the water course right up to the inlet (Naka) of the field, the

possibility of the water supply to the field being affected by extraneous factors like breach or damage to the water course, leakage of water, faulty construction of bed level of the water course, etc. Thus, the actual water availability to a field may not be the same as expected according to the time allocation and may to some extent depend upon the distance of the field from the outlet. As in the case of the outlet, the location parameter of field in the chak may also be an important factor in determining the amount of water available to the field.

Yet another consideration in determining the water supply to the field is its level in relation to the level of the water in the water course. Normally, the field level is lower than the water level in the water course, ensuring uninterrupted water flow to the field. In case, however, the level of the field is higher than the level of the water in the water course, some device for lifting the water would have to be employed. This would entail additional expenditure on the part of the cultivator and may also result in reduced water supply to the field compared to that available from the water course.

Keeping in view the above background, the main questions of interest in a study of this kind, therefore, are :

i. Whether the water level in the canal at different chaks fluctuates from day to day in different periods,

ii. Whether the amount of water actually available is according to the expected availability or the designed discharge,

iii. Whether it irrigates entire culturable command area (CCA), and

iv. Whether the area irrigated gets water timely and adequately to meet the crop needs.

A few other aspects of interest are :

i. Cropping pattern in the various chaks or villages (to study the effect of irrigation on the choice of crops grown),

ii. Extent of adoption of improved practices for various crops, and

iii. Employment potential generated under the system.

Objectives

Keeping in view the aspects and points of interest as outlined above, the survey was planned with the following objectives :

i. To determine the extent of water available and area irrigated,

ii. To investigate the effect of location parameters of the chak and the field on the water supply, and

iii. To determine the extent of adoption of improved agricultural practices and yield level obtained.

Sample Design

The survey was of a pilot nature and covered one distributory in Hissar district of Haryana with a culturable command area (CCA) of about 7000 hectares spread over 52 chaks along the length of the distributory running to about 55 kilometers. The sampling design adopted was a two stage stratified random sampling with chaks as primary stage units and holdings in a chak as secondary stage units. For conducting crop cutting experiments, two more stages of sampling were introduced, the fields growing the crop under study as the third stage units and a plot of given shape and size constituted the fourth stage unit. The sample size was 10 chaks, selected with equal probability without replacement. For convenience of operation, the 10 chaks were formed into 5 crops of two chaks each and a group was assigned to one whole time field investigator. The number of cultivators in these chaks varied between 33 to 104, all of whom received water within a rotation period of 7 days. Accordingly, on each day of the week, two cultivators were selected for observation out of those whose turn for receiving water was on that particular day. For study of water distribution and utilization during the night, one cultivator was selected at random during one night in the week. Accordingly, there were 15 cultivators selected for observation

in each selected chak. In a few cases there was only one cultivator who received water throughout the day and in such cases the sample size was reduced. The number of cultivators finally selected in a chak varied between 12 to 15. Of the two chaks assigned to a Field Investigator, data on various parameters were collected by actual observations for each of the selected cultivators in one chak. Data in respect of the other cultivators in this chak and for all the cultivators in the other chak were collected by enquiry.

5

PRODUCTIVITY AND EQUITY IN GAL OYA LEFT BANK, A SRI LANKAN IRRIGATION SYSTEM*

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The Gal Oya irrigation-settlement scheme is one of the largest in Sri Lanka, covering a geographical area of 600 square miles (1550 km^2). It is located in the south-eastern corner of the country in what is called the Dry Zone, because there is only one monsoon rainy season each year, concentrated between November and February. The average annual rainfall is about 80 inches, and while this may seem like a lost of rain compared with more arid areas under irrigated cultivation elsewhere, growing a second crop between April and August depends entirely on water from the irrigation system, and supplementing rainfall with irrigation during the major crop season is necessary for reasonable yields. Both the main (maha) and minor (yala) crop are almost exclusively paddy.

The scheme was begun in 1948 with the building of a main dam across the Gal Oya river, creating the reservoir (Senanayake Samudra) with a storage capacity of 770,000 acre-feet. This was

* Co-authors are listed in alphabetical order. Wijayaratne and Wickramasinghe are members of the Irrigation and Water Management Group of ARTI; Murray-Rust, St. Julien, Svendsen and Uphoff have worked with the Group in various capacities on behalf of the Rural Development Committee of Cornell University under a cooperative agreement with USAID to support "participatory" approaches to rural development. Murray-Rust is currently on the faculty at Rutgers University and Svendsen is working on water management for the Asia Bureau of USAID in Washington. This paper compiled various pieces of analysis done under the joint ARTI/Cornell project and represents work in process, not completed.

followed by construction of main canals to serve what are called the Left Bank and the Right Bank of the project area. (A Division comprised of areas previously cultivated with water diverted from the river is also served within the system.) Officially the Left Bank (LB) system irrigates 42,500 acres, but estimates of the actual area served (including encroached lands and private, non-settler holdings) range up to 65,000 acres or even higher. Such discrepancies mean of course that estimating "efficiency" of water use is very difficult. The channel system includes 32 miles of main and branch canals (LB Main, Uhana, Mandur, Gonagolla and other branches), 50 miles of major distributaries (called D-channels usually, corresponding to secondary canals in other systems), and about 600 miles of minor distributaries and field channels (tertiaries and quaternaries).

The settlement program initially brought some 6,000 families to settle on about 24,000 acres in 40 colony units. Most of the area was previously uninhabited (though 500 or more years earlier the area had been known as "the granary of Ceylon") and was settled with Sinhalese from the interior highlands and western coastal areas. The project area in the lower reaches was at the time already cultivated by Tamils and many were "resettled" as colonists in tail-end units.[1]

The Left Bank area was chosen for a major rehabilitation effort by the Government of Sri Lanka and USAID in 1978, because of the serious deterioration of the physical system with silted channels, broken structures, and inadequate water distribution. About one-third of the LB command area seldom or never got water in the yala season. The LB households were thus poorer than in many areas. Recognizing that simply refurbishing the restoring the system physically would not make for any lasting gains in productivity and welfare, the main purpose of the project was to improve water management. Both physical rehabilitation and the establishment of farmer organisations for managing water after the rehab work was completed were provided for in the project. To get a better understanding of how water and crops were actually managed in the system

and to have some standard for evaluating progress, a plan for socio-economic and agro-hydraulic baseline and monitoring studies was implemented by the Agrarian Research and Training Institute (ARTI) with technical assistance from Cornell University.

This paper draws on data collected under this program of water management studies. ARTI assigned field investigators to gather data and supervise farmer record-keeping in 17 (approximately half) of the colony units randomly from the Left Bank, plus five units randomly selected from the Right Bank and River Division as controls. Within each colony unit, a distributary channel was identified and field channels at the head, middle and tail of the D-channel in that colony area were selected. If the number of allotments on a selected field channel was less than 20, all were included in the study; if there were more than 20, a random sample of 20 was taken.

The total number of farms/farmers included in the first round of record-keeping and monitoring during the maha season of 1979-80 on the Left Bank was 536. In subsequent seasons this number had to be reduced somewhat due to financial and supervisory constraints. Virtually complete production and household data were gathered, and during the cropping seasons, daily readings were taken of the water flow above, at and below the D-channel gate in the main/branch channel; at the head, middle and tail of the D-channel; and at the head, middle and tail of the three selected field channels (15 readings in all). In addition, the status of water supply was observed and recorded daily for two bunded paddies (liyaddes) for each of the farmers in the sample - one liyadde nearest the pipe inlet supplying water from the field channel, and one farthest from it - to ascertain field level water deliveries. These measures (over 1,000 field readings each day) complemented data on channel flows and provided the basis for the Water Availability Index (WAI) discussed below. The level of water flowing through the pipe inlet was also recorded but analysis relating channel flow, inlet flow and water status in the field has not done so far due to data processing constraints. As can be imagined, the

amount of data generated from this program was immense and only a small part has been analyzed. The field investigators were closely enough supervised by ARTI staff officers, and internal checks on consistency were done, so that we have reasonable confidence in the data.[2]

The physical layout of the system, and the location of various colony units, will be made clearer in the course of this paper. Extensive baseline data on the Gal Oya Left Bank have been reported in the 1980 Yearbook for Sri Lanka Water Management Research.[3] A number of papers have already been written using the data gathered to date and we expect considerably more analyses and publications will be done on this system. Here we will draw on several analyses of data done to date which address questions of "productivity and equity", the subject of this workshop, adding some detailed analysis of how the distribution of water relates to the use of non-water production inputs, and how this in turn serves to amplify or reduce productivity differentials associated with inequity in water deliveries. The analyses offered here can be extended with more data and with consideration of more seasons if we have more time and resources for this work.

I. Productivity and Equity Variables

Although productivity sounds more tangible and specifiable than equity, on examination it nevertheless presents some problems of measurement. Productivity has to be specified with regard to some factor of production such as land, labor or capital. Unfortunately, these are often inversely related, so that the most productive use of labor is not the most productive use of land, or vice versa. One can try to aggregate all factors by denominating them in money terms, and then calculating returns on expenditure, but this assumes that the prices reflect true opportunity costs. It would require estimation of "shadow prices", about which these can also be controversy, to arrive at some figures representing aggregate productivity.

We prefer to begin more simply with physical productivity relationships, addressing returns from the factor of production which is seen as most limiting - land in combination with water. Sri Lanka has relatively abundant labor, and although capital is scarce, it can be multiplied or acquired more readily than can irrigated land area. In this analysis, we will treat as the measure of productivity, the number of bushels of paddy produced per acre or hectare. This is at least relatively unambiguous, and we would argue that it reflects the policy objective of government in Sri Lanka to move toward self-sufficiency in paddy.

In the Dry Zone, land without adequate and reliable water supply is of little use, so when we speak of the productivity of land in this region, we have to be considering water as well. Our production function analysis of farm-level data shows that water application explains half or more of the variance in yields per acre. We could be trying to explain productivity in terms of returns to water.[4] But that would require measurements and conversions beyond our means, so we will follow the simpler, straightforward practice of dealing with productivity in terms of land as the focal factor of production.

There are even more ways of defining and measuring equity. We will not go into the philosophical questions of whether equity means complete equality of conditions, or whether <u>ex ante</u> equality of opportunity is equitable even if there is no <u>ex post</u> equality of outcomes. We assume that with regard to a situation of agricultural production, equity means all producers have something approaching equal access to productive resources, including water, even if not all are able to get the same results. There are some inevitable differences in skill and in factors such as soil or climate. Of special concern here, naturally enough, is equal access to water.

In Gal Oya, because it was a settlement scheme, the original distribution of land was more even than in other parts of Sri Lanka or South Asia. Initial settlers were given four acres of

irrigated land per household, and later ones were given three acres, plus an unirrigated (highland) allotment of up to 2 acres. There has been considerably illegal subdivision and even leasing and *de facto* sale. This has created many smaller plots and some larger holdings than originally provided for. Still, the average holding throughout most of the Left Bank area is a little over two acres (0.9 hectares, with a standard deviation of 0.5 hectares, this means two-thirds are between 1.0 and 3.5 acres). There are some cultivators farming a fraction of an acre and some others have accumulated 10, 20, 30 or more acres under their control, usually rented out in more nearly typical operational units.

One could argue that equity in water distribution would mean that all cultivators get an equal amount of water to use on whatever size holding they operate, thereby equalizing differences in the area of land controlled. We will, given the relative evenness of holding sizes, look rather at whether land areas get similar applications of water, with a view to maximizing total production from the aggregate land and water resources of the area. This may not be agreeable to all, but we would like to proceed in this manner.[5]

Actually, because there are considerable variations in soil quality with regard to irrigation, exactly equal applications of water to each area might well not be regarded as "equitable". Should a farmer who was given sandier soil in the original settlement allocations have to make do with the same amount of water as another settler who got better, more water-retentive soil? That would hardly seem equitable. Some ideas of "adequacy" and "sufficiency" of water supply, as well as reliability and predictability, enter into farmers' calculations of whether they are getting a "fair" share of water for their fields. Determining equity in water distribution is difficult in large part because it is unclear what exactly should be measured. Some absolute standard might require measuring soil moisture in the root zone of each farmer's crop, in which case the measurement would be extremely difficult.

Our research effort has produced some methodological innovations for estimating adequacy of water distribution at the field level which we would like to explain before getting into an analysis of the patterns of water distribution and agricultural productivity on the Left Bank. We think these may be of some use to other researchers and to planners in other schemes and thus go into a little detail on how the two indexes were constructed. Our measures of productivity, it should be said, were derived both from crop-cuttings on the thousand plus fields covered by our sample and from farmers' own reports of their yield. That these two measures are highly correlated (r = 0.95) gave us considerable confidence in both our "objective" and "subjective" measures of productivity. We are able to develop "objective" and "subjective" indexes of water supply also. These had a somewhat lower correlation (r = 0.67) but proved quite satisfactory for identifying patterns of inequity in water distribution within the Left Bank system. Without such measures we could not have addressed questions of productivity and equity as discussed next.

II. Measures of Water Distribution

Direct measures of water delivered to each field would have been exceedingly costly and time-consuming. But also, because soils in Gal Oya vary so much, the most relevant measure agronomically would be the amount of moisture in the plants' root zone, not simply water delivered. ARTI used a simpler but more inclusive observational measure which implicitly adjusted for soil variations.[6] Each day, the water status of two plots was noted for each farmer in the sample and it was scored as follows :

a. severe shortage of water (soil cracking)
b. moderate shortage (soil dry)
c. saturated condition (soil wet)
d. standing water
e. flooding, or flowing water.

On the basis of the conditions observed, a Water Availability Index (WAI) was computed for each farm (average score for the two plots),

using a simple system of weighting, described below, to indicate the degree to which a farm's crop was more or less free from water stress during the growing period.

Because the 50-day period between 20 and 70 days before harvest is considered critical for maximizing yields, representing the water-sensitive reproductive phase of the rice plant, the WAI was calculated for this period. The weighting was as follows : the number of days in the first category (severe shortage) plus the number of days in the second category (moderate shortage) doubled plus the number of days in the third category (saturation) tripled and the number of days in the last two categories (standing or flowing water) quadrupled.[7] Since this was calculated for 50 days, the maximum score would be 200, and the lower the score, the more water stress the crop had to endure.

With WAI calculated for each farm, an average WAI could be calculated for those farms along a field channel, and comparisons could be made between the average WAI for farms along a field channel at the head of a distributary, for those along a middle field channel and those along a tail field channel. WAI could also be calculated for all farms within a distributary area or for all farms at the head, middle or tail of field channels in a distributary area. This would indicate adequacy of water distribution within a system and within sub-systems.

Complementing this was a Water Problem Index (WPI) calculated not for individuals but for farmers in a given channel area. When farmers were interviewed for the baseline survey, ARTI investigators asked them about the adequacy of their water supply and what problems they had. This information was used to construct a reported measure of water availability. Farmers could state that they had no water problems, or that they had too much water, unreliable water, a shortage of water, or no water at all, for both the maha (wet) and yala (dry) seasons. The WPI was calculated by considering only the latter two responses (shortage or lack of water) as they represented more serious probelms than the first two. To get a

weighting of the seriousness of water problems in the channel area, the per cent of respondents reporting no water was double-weighted, and then the per cent of respondents reporting either problem in the yala season was double-weighted. This produced an index number for each area which assigned importance to having insufficient water or none at all, assigning extra weight to having none at all, and further extra weight to problems in the yala season when irrigation is crucial.[8]

These are not the only water problems a farmer can have, but they are indicative of the situation facing farmers in the respective areas. As a validation of WPI, we would note that it correlated even somewhat higher (-0.74) with yield than did WAI (0.70). (The two indexes are, naturally, inversely correlated themselves given the way they are constructed.) We will show results based on this second measure of water distribution later in the paper. In the next section, we will be concerned with water distribution as indicated by WAI. The scores for the two indexes and paddy yield for each unit in the ARTI study are shown in Table 1 on the next page. The units indicated are shown on the map in Figure 1 (page 11 below).

III. Distribution of Water and Yields Within Gal Oya Left Bank System

From the daily measurements in the main/branch, distributary and field channels, it could be seen that reliability, frequency and adequacy of water flow all tend to decrease toward the tail end of channels. However, a simple "distance" conception of head, middle and tail does not hold up under careful examination. We learned this sometimes the hard way, having made certain initial assumptions such as found in the literature and which seemed perfectly reasonable.

In the map on page 11, we show the location of the various units where water flow and paddy yield were measured and show also the initial sketching of "isoquants" of yield, reflecting our conception of the head-tail relationship. Senanayake Samudra, the main reservoir serving the system, is shown in the lower left hand

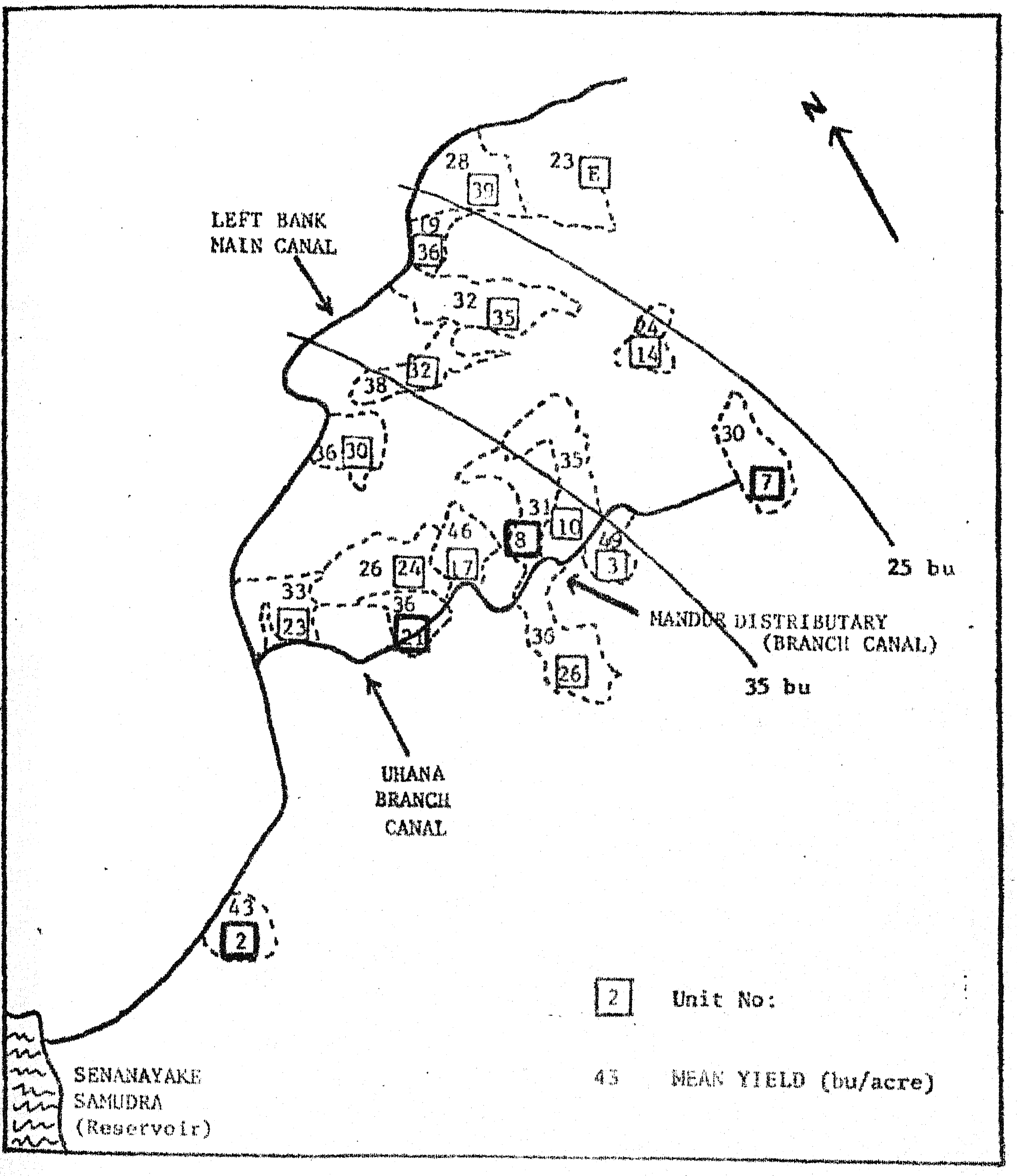
Table 1

Gal Oya Left Bank Study Units Listed by Severity of Water Problems (WPI), Showing Also Water Availability Index (WAI) and Yields (bushels/acre), Maha Season 1979/80

Unit	WPI	WAI	Yield
Category I : Few Water Problems			
23	84	191	32.5
17	96	177	45.9
3	105	193	48.5
Average :	95	187	42.3
Category II : Moderate Water Problems			
21	151	184	36.3
24	162	182	26.0
32	167	182	37.6
2	179	187	43.3
30	184	173	35.8
26	223	196	35.9
10	225	186	34.7
Average :	179	184	30.4
Category III : Serious Water Problems			
8	294	168	31.0
J	316	114	25.1
14	360	168	23.5
39	385	NA	28.1
7	445	167	29.5
35	448	NA	31.6
Average :	375	154	28.1
Category IV : Extreme Water Problems			
D	625	NA	19.4
E	641	148	23.5
Average :	633	148	21.4

Figure 1:

Left Bank-Gal Oya Yields of Sample Units - Maha 1979/80



corner of the map (page 11), so the "tail" was seen as lying in the upper right hand areas, with intermediate areas as the "middle". The yield data gathered from the sampled units for the maha season 1979/80 are shown on the map next to the unit numbers. One of the difficulties we found in our study was that yields varied considerably season-to-season, even though one might expect irrigation to have stablized yield. In fact water deliveries and rainfall were varied and even erratic. The season-to-season fluctuations can be seen from Figures 4, 5 and 6 for the three seasons after maha 1979/80. But analysis of this would be the subject of still another paper. We would assert in any case that a one-season or even one-year survey does not provide a proper "baseline" for future comparison and evaluation.

Some idea of the variations in water distribution can be seen from charts in an appendix to this paper which show the depth of flow in the channel systems serving different units at the head, middle and tail.[9] The relatively even flow in the Left Bank main canal can be seen from the first figure (1-M). Even the distributary serving Unit 2 (LB6) has some differential in the maintenance of flow to the tail as seen by comparing Figures 1-DH and 1-DT. What is most striking is the falloff in deliveries to the tail of the three field channels monitored. Actually, the yields in this area are above average for the Left Bank, though not the highest (as one might expect). The overall water situation is relatively favourable even with distribution problems within the field channel system. This area was settled with households displaced from the reservoir's catchment area. They were not willing settlers and their agriculture had been shifting cultivation rather than irrigated paddy. Even 30 years later, their cultivation practices and their cooperation for irrigation purposes (cleaning field channels and rotating water among fields) leave much to be desired. It is interesting that, given sociological factors of this sort, some areas in this head-most unit can experience water shortages.

Unit 21 is served from the Uhana branch canal and is within the head-end area of the Left Bank system. The distributary UB9 passes

through the unit and on into Unit 20, which represents the tail-end area for UB9 command area. So we do not see much falloff in deliveries as the tail for Unit 21 is still in the middle reaches of UB9. We do see that even the field channels in Unit 21 experience some decline in water flow in the tail area and we know that there has been considerable decline in water reaching the tail areas in Unit 20. This distributary command area is one of those where Institutional Organizers (IOs) recruited and trained by ARTI have been posted to establish farmer organizations for water management. In the last two yala seasons, with farmer cooperation and no increase in water issued to UB9, it has been possible to serve the whole command area adequately by instituting rotational distributions, sending water to tail-end field channels during the first days of each issue when necessary, and by closing the pipe inlets of head-end fields along each field channel for the first few days. This system has sometimes broken down, especially when the main system issues have been changed without notice, but on the whole considerable improvements have been possible by farmer effort and initiative.

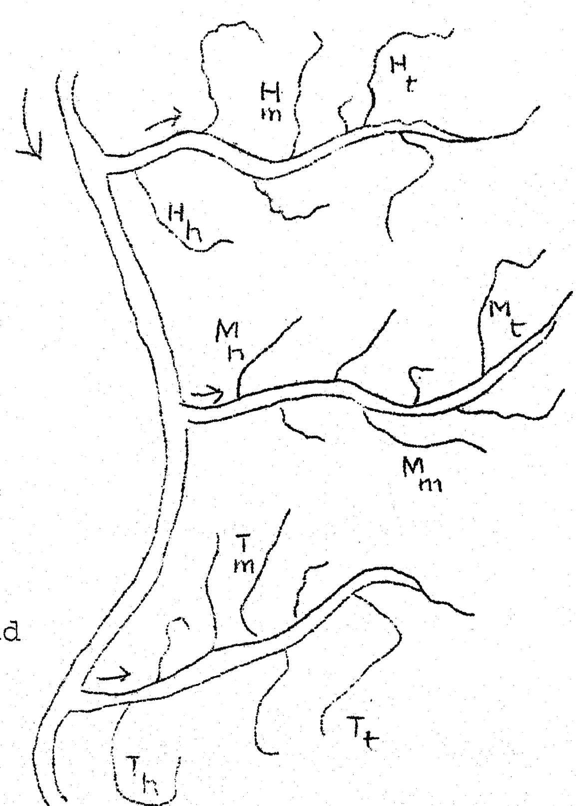
Unit 8, served by the Mandur branch canal, is in the middle of the system. The water deliveries are less adequate overall, though the particular D-channel has the advantage of being located immediately upstream of a major regulator, so its head of water is higher than for many other D-channels. This advantage is reflected in the flow readings for the two Unit 8 field channels shown. Both are well-placed relative to the rest of the large and complex network of channels making up the M5 command area. Also, flows within these field channels are relatively even between head and tail. We have not done enough sociological studies in this area and the organizing efforts there are just beginning this month in the M5 area, so we can only surmise that with the relatively smaller supply of water, some informal mechanisms have been instituted by farmers to get more equal distribution. We do not know the details of flow in the tail reaches of M5, but will be undertaking organizational work there too. We know that there were crop failures in the tail end areas of M5 distributary in both 1980 and 1981 yala seasons.

When we come to Unit 7, which is in the tail area, we see that in the maha season, it got virtually no water. The one issue which reached the field channel monitored arrived when the crop was already mature. The circumstances in the yala season, when any crop depends entirely on irrigation, are usually no better in this unit, so no crop is planted as a rule.

This quick overview of water flows within the Left Bank system, showing channels where measurements have been graphed, sets and stage for discussing the distribution of water and yields more systematically. But first, we should offer a schematic diagram (Figure 2) which makes clearer the references to subsystem areas we will be comparing. The temptation was to draw a neat geometric layout of main, distributary and field channels, with head, middle and tail of each laid out in perfect proportions. Our work in Gal Oya has made us acutely aware of how ungeometrical and how unsymmetrical the actual channels and command areas are, at least in Gal Oya, if they are to take advantage of the "energy" which powers any such irrigation system - gravity. There have to be some long and irregular channels to serve the commanded area, and the soils that are irrigable are not necessarily the best or even good. Figure 2 does not show the kind of intricate net-work of sub-field channels and sub-sub-field channels which we (and farmers) have to deal with in reality. In practice on the Left Bank, we have field channels

Figure 2

SCHEMATIC CHANNEL LAYOUT OF HEAD, MIDDLE AND TAIL AREAS OF MAIN, DISTRIBUTARY AND FIELD CHANNELS



that serve as many as 200 acres (with some sub-field channels, of course, but only one turnout from the D-channel) and some D-channels directly off the main or branch canals that serve as few as 20 acres. So even Figure 2 is highly idealized for purposes of exposition. Some of the most overlooked problems of inequity in distribution come not simply from the gross differences dictated by the natural laws of gravity and distance which are quite predictable but from the quirks of topography and soil quality.

Figure 2 depicts head, middle and tail distributaries off a main canal, with head, middle and tail field channels shown off each D-channel. Our analysis here compares the Water Availability Index and the yields for farms in these nine areas. The figures for this analysis are shown in Tables 2 and 3 on the next page.

The D-channel areas for which the analysis was done are two or three in each situation - D-channels in Units 2 and 21 as head areas, Units 8 and 10 as middle areas, and Units 7, 14 and E as tail areas.[10] The most consistent and important differences are in water availability and yield between head, middle and tail D-channels, shown in the right-hand column of Tables 2 and 3. The differences shown in Tables 2A and 3A, between head, middle and tail field channels within a head, middle or tail location are not as great, and not always in a consistent direction. The size of sub-samples was between 30 and 50, so there may be some margin of error in the figures, but we think they are reasonably representative. That yields in tail field channels are not as low as expected based on water deliveries can be due, at least in some instances, to the effects of drainage water, an underestimated factor in both planning and evaluation of irrigation systems (ignoring farmers' innovations to exploit all available water). Also many tail-end areas have soil with more clay content and therefore do not suffer from reduced water supply to the same extent.

We have analyzed separately the water availability and yields on farms where were at the head, in the middle, or at the tail of

Table 2

Differences in Water Availability Index (WAI) by Field Channel and Farm Position

Table 2A	Head FCs	Middle FCs	Tail FCs	Average
Head D-Channels	190 (H_h)	186 (H_m)	184 (H_t)	186
Middle D-Channels	181 (M_h)	176 (M_m)	175 (M_t)	177
Tail D-Channels	164 (T_h)	166 (T_m)	151 (T_t)	160
Average	178	176	170	174

Table 2B	Head Farms	Middle Farms	Tail Farms	Average
Head D-Channels	186	183	185	185
Middle D-Channels	180	177	175	177
Tail D-Channels	166	152	161	160
Average	177	171	174	174

Table 3

Differences in Yield (Bushels Per Acre) By Field Channel and Farm Position

Table 3A	Head FCs	Middle FCs	Tail FCs	Average
Head D-Channels	44 (H_h)	37 (H_m)	45 (H_t)	40
Middle D-Channels	39 (M_h)	29 (M_m)	31 (M_t)	33
Tail D-Channels	23 (T_h)	23 (T_m)	27 (T_t)	26
Average	35	30	34	33

Table 3B	Head Farms	Middle Farms	Tail Farms	Average
Head D-Channels	52	34	40	42
Middle D-Channels	36	28	40	35
Tail-D-Channels	22	30	25	26
Average	37	31	35	34

Note : Averages are unweighted and rounded, so are not exact in all cases.

Sources : Tables 2-1, 2-2, 2-4 and 2-5 of 1980 Yearbook, op. cit.

field channels within a D-channel area (Tables 2B and 3B). There is more difference between WAI and yields on head field channels compared to tail field channels, than between head farms and tail farms, indicating that in general, it is more advantageous to be located on a field channel at the head of a D-channel command area, even at the tail of that field channel, than to be simply at the head of a field channel, say, at the tail of the D-channel. Of course, many other factors than simple location come into play affecting both water availability and yield, so we do not want to make too much of this.

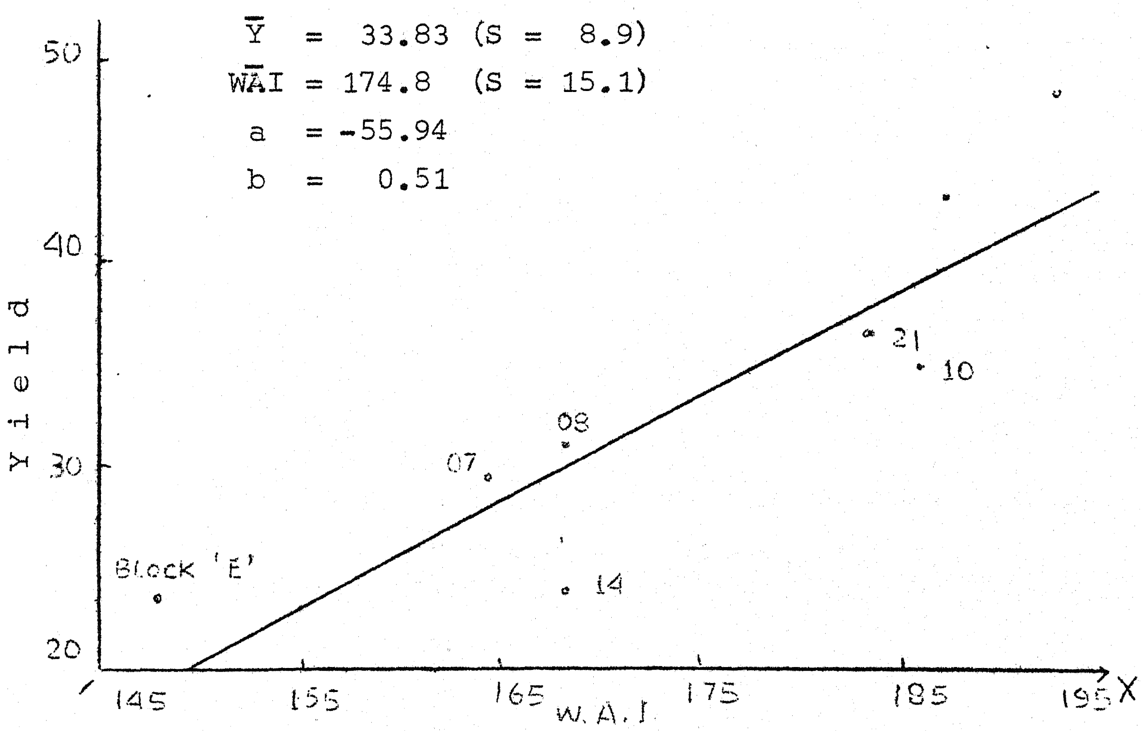
We can get some indication of the priority of water availability by calculating rank-order correlations between WAI and yield according to different sequences of location within the system : (A) head D-channels first, i.e. according to the notations in Figure 2 - H_h-H_m-H_t-M_h-M_m-M_t-T_h-T_m-T_t; (B) a modified "diagonal" sequence - H_h-H_m-M_h-H_t-M_m-T_h-M_t-T_m-T_t; and (C) head locations near the main channel first - H_h-M_h-T_h-H_m-M_m-T_m-H_t-M_t-T_t. The respective correlations for these sequences with WAI are : 0.98, 0.93, and 0.55, while the correlations for these sequences with yield are : 0.85, 0.75, and 0.26. This underscores the significance of differences in WAI and yield <u>among</u> D-channels compared to differences <u>within</u> D-channel areas or between field channels.

The general relationship between water availability and yield at the unit or D-channel level is shown in Figure 3, with the plotting of a simple regression of yield on WAI for the 1979/80 maha season. One cannot expect a perfect relationship between yield and WAI, though the simple correlation coefficient was 0.88, and the R^2 was 0.77. This close statistical fit is heightened in part by the aggregated units of analysis, but as we will see later, it is still rather close when disaggregated further with data for the following three seasons. This shows us that production, even

in maha season, depends predominantly on water. There are other factors affecting yield - on-farm water management, pest and disease attacks, application of fertilizer, hand weeding or use of herbicides, and other aspects of crop management. WAI does reflect certain qualities of soil (e.g., soil hydraulic conductivity, depth of water table) and also farmer water management practices (e.g., levelling, bunding, etc.). But it does not indicate certain other aspects such as soil fertility. In addition, as presently calculated, it does not distinguish between continuous and intermittent water stress on the growing crop.

Figure 3

RELATIONSHIP BETWEEN MEAN YIELDS AND MEAN WATER AVAILABILITY INDICES OF UNITS



Y = a + bx, where Y = mean yield, and x + mean WAI for each unit; the correlation coefficient (r) = 0.88; r^2 = 0.77

Still, given these qualifications, we find WAI a useful indicator and find rather definite relationships between WAI and yield. We have done linear regressions of yield on WAI with data aggregated only at the field channel, not the D-channel level, for three seasons (yala 1980, maha 1980/81 and yala 1981). We have also drawn isoquants on maps of the Left Bank area for the three seasons showing levels of water availability and yield (Figures 4, 5 and 6).[11] What is most instructive is to note how much more refined the analysis is compared with Figure 1, where a much simpler relationship was indicated between distance from the main reservoir and water/yield levels. We find quite irregular isoquants, reflecting relatively high water availability all along the Uhana branch canal and down into the areas served by the Malwatta, Chadayantalawa and Sammanthurai distributaries (these function more as minor canals than as D-channels). Regressions of yield on WAI are shown for each season in Figures 4-6. Given the qualifications noted above, the R^2 values showing the strength of relationship between the two variables at this level of analysis are surprisingly high. When data for all three seasons were combined, the summary relationship resulted:

$$\text{Yield} = -32.35 + 0.48\ \text{WAI}\ (R^2 = 0.46;\ N = 72)$$

Given the maximum and minimum levels of water availability, on the basis of this equation the average maximum and minimum levels of productivity for the Left Bank would range between 64 and 27 bushels per acre.

In a separate analysis, multiple linear regression was done to consider the effects of water stress together with other inputs such as fertilizer applications, labor input, etc. In the most satisfactory model (for yala 1980), more than half (57%) of yield variability was still accounted for by water alone. This finding strongly supports the results of the simple linear regression relating yield directly to water availability.

The location of farms was found to be the most important single factor which determines a farm's WAI. The outcome of the

Figure 4:

LINES OF EQUAL WATER AVAILABILITY (WAI) IN GAL OYA, LEFT BANK, AND A SIMPLE REGRESSION OF YIELD ON WAI, YALA SEASON 1980

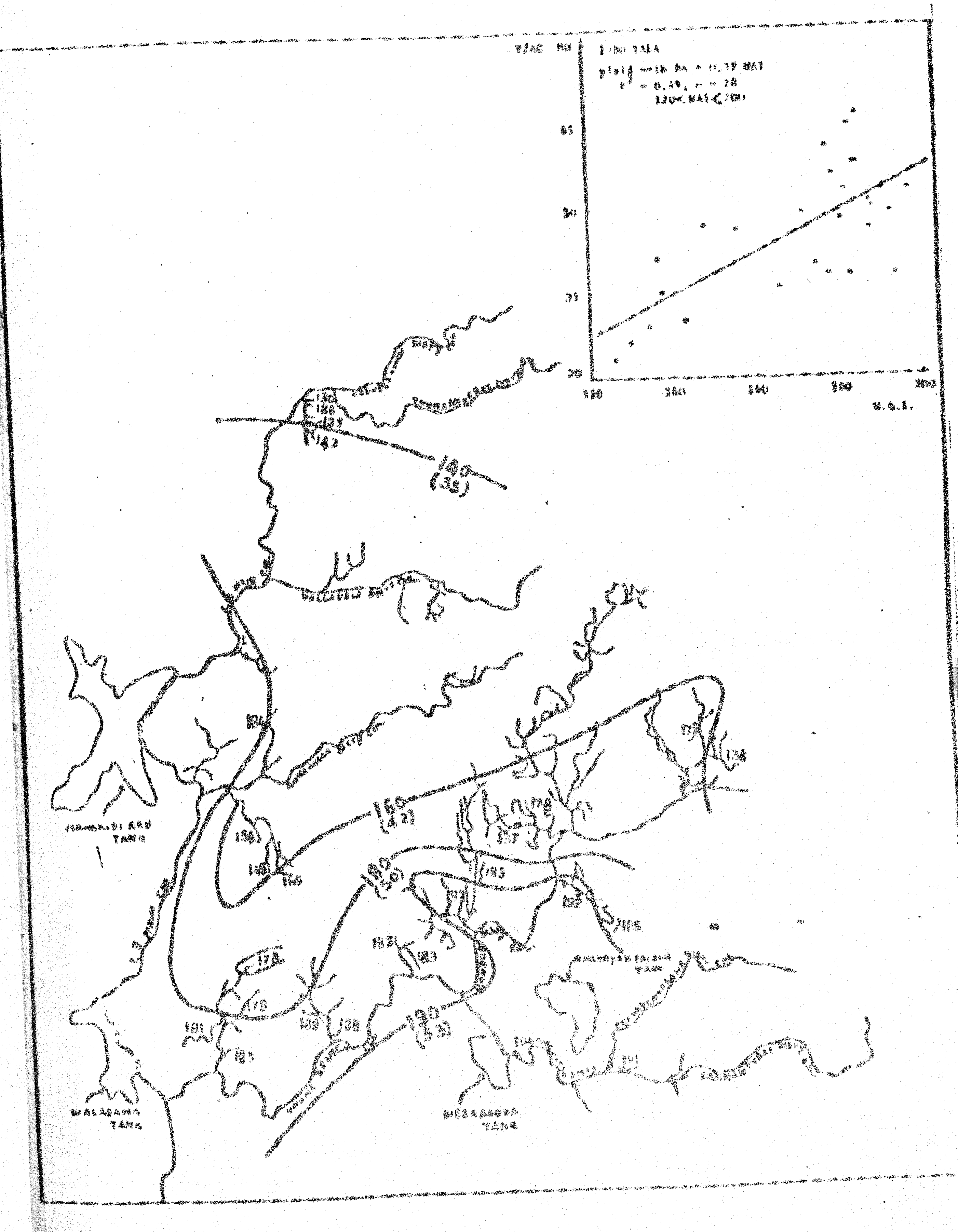


Figure 4:

LINES OF EQUAL WATER AVAILABILITY (WAI) IN GAL OYA, LEFT BANK, AND A SIMPLE REGRESSION OF YIELD ON WAI, YALA SEASON 1980

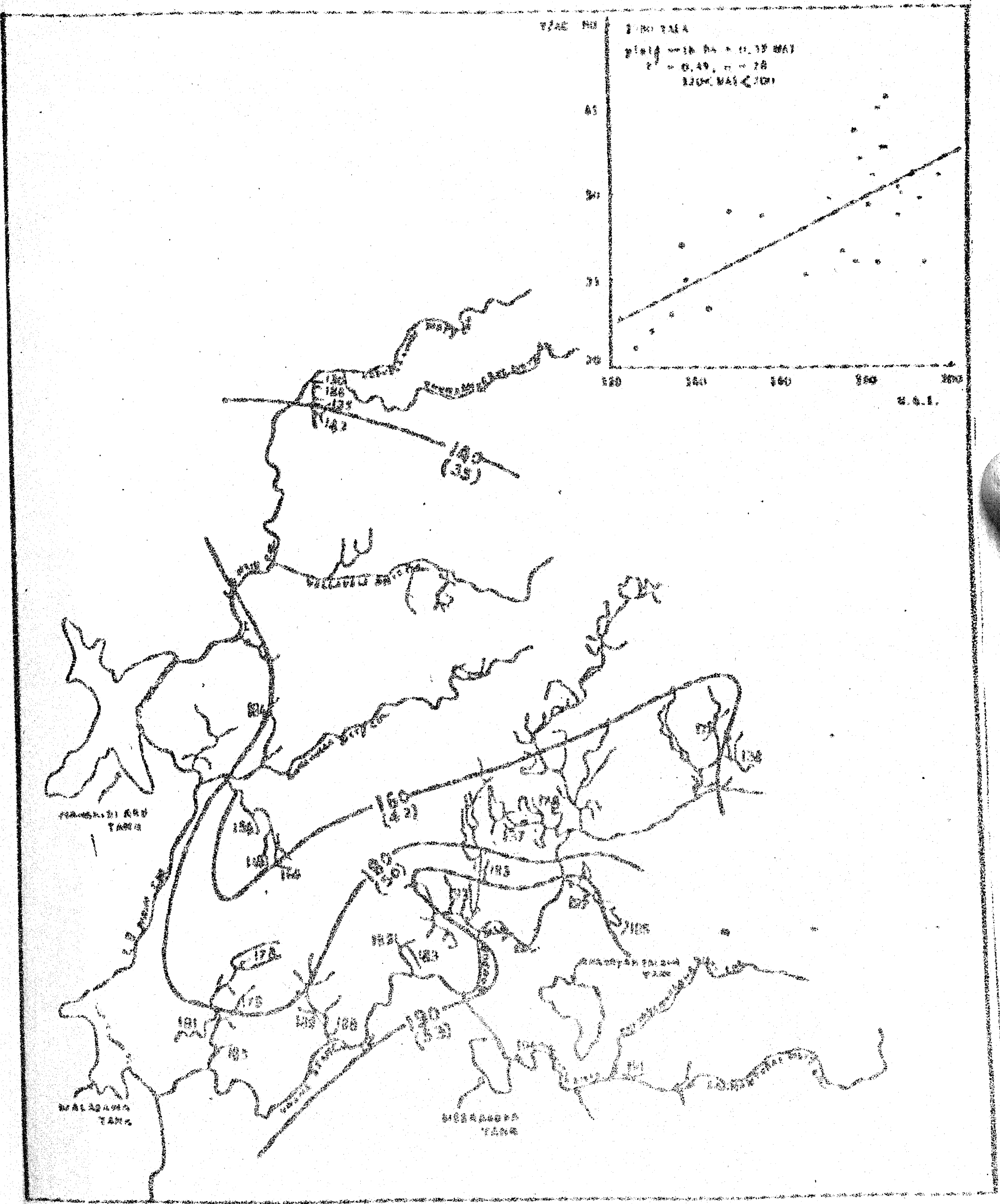


Figure 5:

LINES OF EQUAL WATER AVAILABILITY (WAI) IN GAL OYA, LEFT BANK, AND A SIMPLE REGRESSION OF YIELD ON WAI, MAHA SEASON 1980/81

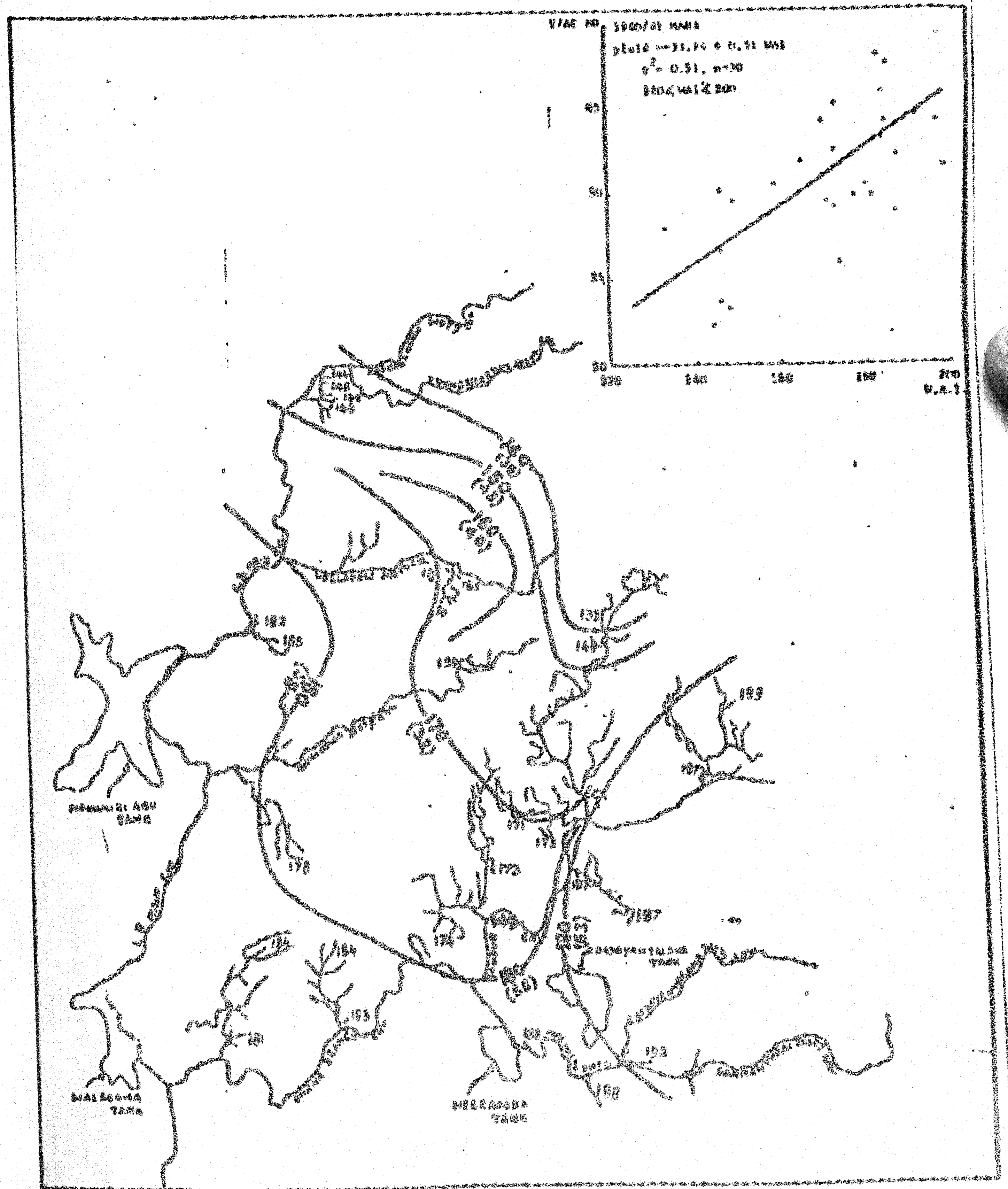
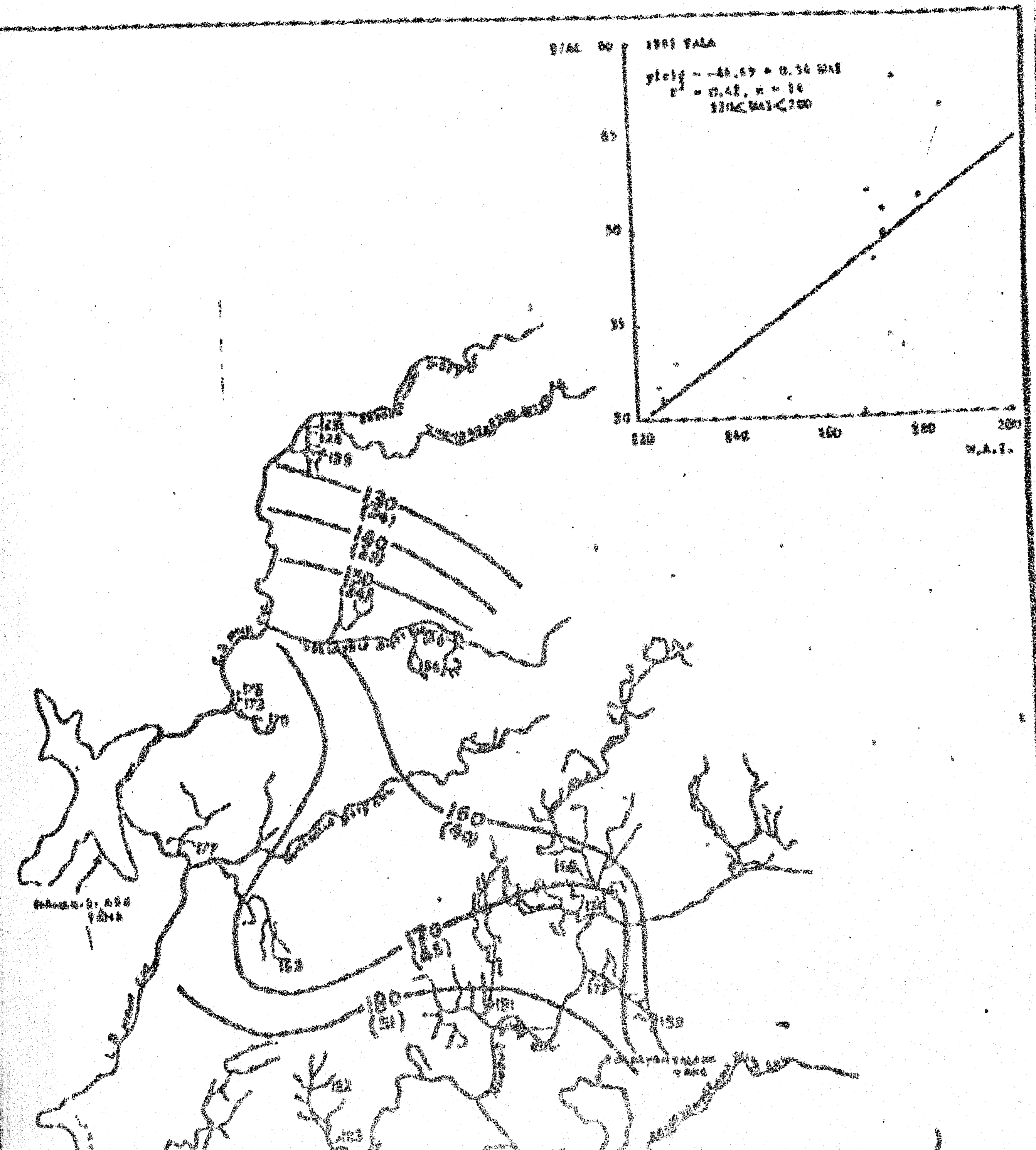


Figure 6:

LINES OF EQUAL WATER AVAILABILITY (WAI) IN GAL OYA, LEFT BANK, AND A SIMPLE REGRESSION OF YIELD ON WAI, YALA SEASON 1981



analysis of the relationship between location and respective yield levels over four consecutive seasons can be summarized as follows. First, there was no significant correlation between yield and location of farms along the field channel. The location of field channels along the distributary also did not appear to influence the level of yields of farms along the respective field channels, whether they were at the head, middle or tail. Given the smaller size of sample at this level, the factors cited earlier would have diluted any real relationship between yield and WAI at the field channel level. However, as expected, variation among distributaries was seen to be significant, and mean yields of farms located on the tail-end D-channels were substantially lower than for head and middle D-channels.

To some extent, these gross head-tail differences can be attributed to deficiencies in main system management, as Wade and Chambers have characterized the problem.[12] Improvements in such management should be able to correct at least some of the inequality of water availability in Gal Oya. But the Left Bank system is in such deteriorated condition that even with more sufficient personnel and more adequate communication and management procedures within the Irrigation Department, which are unfortunately lacking, the control over water distribution among D-channels is minimal.[13] In only 3 out of 14 units studied was there any evidence that the D-channel offtake had been closed for at least a day when water was flowing in the main or branch canal, and at only a few locations had the gates been operated so as to alter significantly the flow of water entering the D-channel. The reasons for this were: broken gates (an increasingly severe problem the farther downstream one goes on main and branch canals); lack of effective operation by lower-level staff of the Irrigation Department; and farmers opening gates by themselves with homemade wrenches if the gates have been closed by ID staff. The consequences of these shortcomings in control over water in the main system is that D-channels in the upper reaches get water at will (and sometimes in excess

when gates are not or cannot be closed) and there is then not enough water to serve the lower reaches.

Lest this be thought to explain fully the differences in water distribution and yield, we should add other factors observed in the Left Bank, some of which have been alluded to already. First, the channel configurations are very irregular, with immense variation in length and in the number of bifurcations of flow before a given farm is reached by water from the main system.[14] Some of the most complex and difficult D-channel and field channel systems unfortunately are found toward the tail, as topography dictates divergence downstream and therefore greater lengths. Second, even if some offtakes have not been tampered with, they are not always set at the same level and some are thus more favorably situated than others. We noted already the situation with regard to M5, where being upstream of a regulator gave it better flow and head. Such differences in structural features of D-channels will modify the effects of "distance" as a simple measure. Third, there are effects from differences in channel condition, due mainly to lack of maintenance. The Irrigation Department is supposed to maintain D-channels down to the last half mile (or length serving less than 50 acres), but this has not been possible due to inadequate funds and difficulties in controlling contractors and laborers doing the maintenance work. Farmers are supposed to maintain field channels (and the tail ends of D-channels) but the mechanisms for organizing and enforcing this work have been deficient. Only now with farmer organizations being introduced has much maintenance work been done to improve channel flows. Fourth, there are differences in soil quality which mean that the agricultural value of given amounts of water delivered will vary from area to area, even field to field. The WAI reflects soil quality, but in the absence of a management system which gives more water for sandy soils and less water for soils with more clay content, there will be inequities even if the water delivered is the same for all areas. Fifth, there are differences in the political connections which farmers in certain areas

have -- the ability to get claims for more water heard and attended to. There is limited capacity to control water within the main system, as we have noted, but some of the areas which are best watered are known also to have political "clout" and even if they lie more toward the middle than the head their WAI is much higher than would be otherwise expected. There may be a sixth factor, which represents topography and hydrogeology, such that some areas, e.g. Units 3 and 26, get more drainage and seepage water than other areas. These areas lie toward the River Division, the natural drainage system for Gal Oya, which could help to account for why certain "middle" areas fairly far down the system get such high yields, correlated with high water availability (WAI) as seen in Figures 4-6.

Some of these factors should contribute to greater water and yield differences <u>within</u> D-channel or field channel command areas -- channel configuration and bifurcations, inadequate maintenance of channels, differences in soil quality -- while others -- defects in D-channel offtakes, political influence, and topography and hydrogeology -- should mitigate a simple head-tail "distance" factor to explain water and yield differences. With all these qualifications introduced, the main "pattern" discerned in the Left Bank area is an overall advantage at the head end and ultimately acute disadvantage at the tail, with some of the factors mentioned above giving some advantage to certain areas within the "middle".

There is controversy whether improving main system management with physical rehabilitation of the system, to distribute water more equitably among D-channel areas, would result in gains in productivity, though there would be some improvements obviously in equity. The exact area served by the Left Bank channel system, as noted at the outset, is not known for certain. Some of the private lands area, left with prior inhabitants of the Left Bank or their descendents, gets water from the system, often drainage water, but it is not figured in most estimates

of the extent served. Also there has been major expansion through encroachments of the area getting water directly or indirectly from the system. Many of the encroachers are sons and daughters of original settlers, trying to scrape out a living on fractional holdings. But in some cases there have been powerful outsiders moving into drainage areas and taking control over them, usually renting the land out in small parcels to second - and third-generation settlers. In the case of large holdings, there may be an equity issue to be addressed. But where the "excess" area is one, two or three acre holdings worked by households perhaps even poorer than registered settler households and re-using drainage water through ingenious methods, it is not clear that taking water away from them will enhance equity, except by serving similarly poor households who have a longer-standing claim on the water. The seepage and percolation losses of transmitting the water farther may mean that fewer total poor households are served thereby, so it is indeed a complicated matter. It is doubtful whether there is enough water available each season from Senanayake Samudra to serve the entire de facto command area even with the best possible water management practices by farmers.

The program to improve water management in Gal Oya under the Water Management Project which the Government of Sri Lanka and USAID have sponsored, has yet to grapple with this problem. Having farmer groups able and willing to utilize water economically -- by having done good channel maintenance, by rotating water within field channels and among field channels to get adequate and even water distribution to all fields, and by closing off turnouts and gates as soon as enough water has been received -- is an important step toward redressing differences in water availability and production, and farmers at the head end have shown themselves more willing to accept such activities and responsibilities than we had anticipated. But the broader questions of equitable distribution remain.

IV. FARMER RESPONSES TO DIFFERENCES IN WATER AVAILABILITY

There are a number of ways in which farmers can respond to situations of unequal water distribution, which includes uncertainty of supply as well as overall inadequacy. Elsewhere we have looked in more detail at farmer preferences under differing conditions of water abundance, shortage and absolute scarcity.[15] Farmers were asked in the baseline survey (1980) whether they preferred to have water managed by a government officer, a farmers' council or committee, or a traditional irrigation headman (vel vidane or watte vidane). Comparing responses to this question with the severity of water problems in the farmers' respective areas, as measured by the Water Problem Index (WPI) discussed previously, we were able to draw some conclusions about this which will be reported here in brief.[16]

To begin, those units which favored having a government officer handle water distribution had an average WPI of 137, very low compared to 253 for those units favoring a farmers' council, or 437 for those units preferring a vel vidane. (Overall, 41 per cent of farmers favored a committee system, and 27 per cent each favored government officers and vel vidanes). The correlations of WPI with preference for government officer and for vel vidane were the perfect inverse of each other, - .75 and .75 respectively, and plotting the data showed the relationship in both cases to be reasonably linear. Farmers with the least water problems preferred having a government officer handle water management and were least disposed to suggest giving such responsibility to a vel vidane; farmers with the most serious water problems were quite negatively disposed toward government officers and strongly favored having vel vidanes.

The correlation of WPI with preference for farmers' countil was -.28, fairly low and not significant, but in fact this was because the relationship between WPI and preference for farmers'

council was curvilinear rather than linear. Indeed, a U-shaped curve had been posited previously on theoretical grounds and was supported statistically, when a curvilinear equation produced a rather high $R^2 = 0.54$. This was almost the same as the R^2 for the other two linear equations: 0.56 ($R = 0.75$).[17] The theoretical proposition was that where water is abundant, one would expect farmers not to care to invest their time or effort in participating in decision-making or implementation of water management. Instead, they would be satisfied to let an official perform these duties, since farmers would be getting enough water anyway. At the other extreme of scarce water supply, the most tenable rule for allocation would be equal shares based on some fixed criterion (water per capita or per acre), and this would only need to be implemented and enforced, again not necessarily requiring participation by farmers or their representatives since "rationing" of water would be relatively straightforward. In some "middle range" of water availability or water problems, broader participation would be cost-effective for farmers since some "optimization" rather than simple "rationing" would be possible and desirable. This mode of water management would require considerable input of information into decision-making and would require negotiation and compromise of competing claims toward the goal of maximising total production from the available water supply, taking local, even field-to-field variations into account.

This formulation may be "too neat", though the data quite conveniently support it. One qualification is that some kind of collective action by farmers in water-scarce areas may "pay" even if a single individual acting in an executive capacity can handle water distribution satisfactorily. Where some group action can improve or maintain channels, can acquire water from other sources or can lobby for government investments/decisions to improve the water situation, farmers have an interest in more than a headman institution for dealing with water problems. What we could see from the data was a disposition for farmers

who had water problems of moderate to great severity to prefer decision-makers handling water who were accountable to the community of water users, rather than to bureaucratic superiors. There has been some suggestion in the past that water problems are likely to be so divisive hat some "outside" and presumably more impartial decision-makers should be engaged in water distribution roles. Certainly this is not the implication of farmer responses in our study and in our experience with farmer organization for water management in Gal Oya to date. Indeed, to our surprise, even farmers in head-end areas of Uhana branch have been rather willing to take on responsibilities for water distribution and even some water saving to assist tail-enders in their D-channel area and also downstream. It turns out that in Gal Oya at least, even many head-enders have water problems, such as seen from the pattern of water flow in field channels for Unit 2 (Figures 1-F-1, 1-F-2 and 1-F-3). We have found that when mechanisms have been proposed and assisted by ARTI organizers to institute field channel and D-channel associations for water management, so as to reduce inequities within the system, the farmer response has been positive. Farmers who are "selfish" in private -- that is, who waste water and will not make an effort to use water more efficiently as long as no issue is made of this -- will be more "generous" when everyone's behavior in using water is made a public issue through group discussions and decisions. We are still trying to learn more about how and why farmers may take responsibility for water management, at different levels as well as for different tasks. Our conclusion so far is that when faced with inequalities in water distribution, more participatory rather than more bureaucratic (top-down regulatory) mechanisms seem to be desirable. At least we have found ample basis for experimenting in this direction.

Another kind of response which we would like to explore here concerns the use of complementary production inputs when water is unequally distributed. Does this discourage use of higher technology inputs, so that yields are correspondingly further

depressed and the production consequences of water distribution inequities tend to aggravate inequality within the system? Or are inputs of labor, fertilizer, etc. increased to compensate for water differences, in order to meet household survival needs? We have done some econometric analyses to get some answers, at least tentative, to these questions.

To compare input use for different levels of water availability, we divided the sample of farms covered in the 1980 yala season record-keeping into three groups. The level of WAI = 150 was taken as a critical breaking point since below this, a field would on average have a daily score of less than 3 (soil saturated) and plants would be in more or less constant stress. If, on the other hand, the plants were at least half the time in moist soil (WAI = 175) these water conditions can be considered good if not ideal (WAI = 200). So, we have analyzed the farms falling in three categories: WAI 175 or higher; WAI between 150 and 174; and WAI less than 150. The data are not complete for all cases, but the size of these groups is respectively: 316, 93 and 27, in our yala 1980 sample, for a total of 430. The average statistics for the three groups are shown in Table 4.

Table 4

FARM PRODUCTION STATISTICS, BY WATER AVAILABILITY STATUS OF FARM

	WAI 175 or more	WAI 150 to 174	WAI less than 150
Average farm size (ha)	0.88	0.93	1.15
Average yield (kg/ha)	2735	2287	1682
Total Labor Inputs (man-day equivalents per ha)	98.6	88.2	74.7
(Family Labor)	(51.1)	(38.7)	(25.0)
(Hired Labor)	(36.2)	(42.8)	(49.7)
(Exchange Labor)	(11.1)	(7.8)	(0.0)
Power Traction (Rs/ha)	828	771	516
Fertilizer(nutrients kg/ha)	112	103	133
Plant Protection (Rs/ha)	222	211	203
(Weedicides)	(138)	(128)	(77)*
(Insecticides/Fungicides)	(84)	(83)	(126)*

*It appears that because brown leafhopper was a more serious problem at the tail, farmers in this category "shifted" expenditure between weedicides and insecticides.

As noted earlier in the paper, the average size of holding is somewhat larger (30 per cent) for the poorly-watered holdings compared to the best watered ones. This does not fully compensate for the lower productivity on the poorly-watered farms because their average yield per hectare is 40 per cent less. The total labor input per acre is 25 per cent less on the poorly-watered farms, reflecting particularly differences in broadcasting vs. transplanting techniques of sowing. On the average, labor productivity is lower on the poorly-watered farms. The amount of family labor invested per acre on the poorly-watered farms is about half that on the best-watered ones, and the (unpaid) exchange labor is nil, whereas hired labor is 28 per cent more. Less power traction is employed in land preparation and other tasks as well (38 per cent less). Fertilizer inputs are higher per acre on the more poorly-watered farms (19 per cent higher), which is not expected. Per acre expenditures on plant protection chemicals are roughly comparable across the water availability groups, though the mix of weedicides and insecticides is quite different, probably reflecting different incidences of leafhopper infestation at the head and tail during the season in question. More analysis can and should be done with the data gathered, such as constructing average and marginal returns to different factors of production.

V. CONCLUDING OBSERVATIONS

It must come as no surprise to anyone that there are substantial differences in water delivery and water availability between the head and the tail of the Left Bank system in Gal Oya, Sri Lanka. Moreover, the disadvantages which tail-enders have consequently in terms of lower yields and incomes are also not unexpected. On the basis of three years of field studies by ARTI and Cornell, however, it is possible to indicate the magnitudes of such differentials and to make a number of observations qualifying the simpler formulations about head-tail inequities.

(1) Head-ness and tail-ness are multi-dimensional. There can be water deficiencies in head-end areas given

topography, channel configurations, soil variations, social problems, etc. We have documented such shortages within the head-end reaches of the Left Bank. Yet there is no question that overall the head-end area has great advantages over the tail-end area in terms of water supply.

(2) Distance per se is not an adequate dimension to account for differences in water availability and production. We found some "middle" areas with better water supply and yield than most "head" areas, due to a combination of hydrogeological, configurational and political reasons. Also, our studies showed that the number of bifurcations above a given farm was more important in influencing water supply than simply the distance in linear terms from the water source.

(3) The inequalities associated with water distribution are likely to be multiple and cumulative. In the Left Bank area, tail-end households must seek off-farm employment to supplement income, and the returns to such labor are even lower than for own paddy production it appears. The figures in Table 4 suggest that the pattern of production in less-watered areas, surprisingly, is more dependent on inputs paid for in cash, giving farm operators less flexibility than if family labour and other non-cash inputs are more important. Further, something not dealt with here but well shown by Mick Moore and associates is the concentration of public facilities like schooling, health care and government offices at the head and their corresponding inadequacy at the tail.[18] So the means for redressing locational disadvantages are less accessible to tail-enders.

The systematic analysis of productivity and equity differentials within irrigation systems is only just beginning. There are some very clear general patterns, but we need to avoid gross generalizations when it comes to taking measures to improve both total productivity and total equity in any system. We will hope to be able to contribute more to this field of study from our subsequent work on data from Gal Oya.

Footnotes

1. This characterization is a simplification in that there were some Sinhalese living in the interior in purana (traditional) villages who remained as private landholders outside the colonization schemes, and there are also Muslim communities toward the tail which though Tamil-speaking have their own cultural identity. In gross terms, we are dealing with a large Sinhala settler population in the head and middle reaches and a smaller Tamil population at the tail.

2. Production functions with yield regressed on a set of production inputs including water have given R^2s ranging up to .90 and even higher, suggesting that the relationships within the data sets are too consistent to have been cooked up by scattered investigators having no training in such esoteric estimations.

3. This yearbook, titled Initial Analysis of Pre-Rehabilitation Situation in Left Bank, Gal Oya, 1980, has been published by ARTI (1982).

4. Robert Chambers in an earlier, seminal ARTI publication, Water Management in the Dry Zone of Sri Lanka (1975), has argued that water rather than land is the principal constraining factor and that all calculations and policies should be reoriented accordingly. Unfortunately this is easier said than done.

5. A study of head-end and tail-end colony units in Gal Oya by Shyamala Abeyratne has found that the average size of holding per household is greater at the tail than at the head. This reflects and to some extent compensates for unequal water distribution. Given the growing population in the area, there is tremendous pressure to subdivide original allotments to accommodate the second generation (and now third generation). In the better-watered head-end areas, allotments can be divided and still support more than one family at a tolerable level, whereas at the tail, where irrigation water is lacking, holdings are not productive enough to be subdivided. Indeed, households are larger at the tail in part because land cannot be so readily divided up and also because there is need for a larger household labour force to plant quickly at the time of the initial rains since agriculture is only rainfed at the tail. Because households at the tail are mostly Tamil rather than Sinhala, differences in size of households have been attributed to ethnic factors, but these material factors are definitely at work. See A Study of Second-Generation Settlers in the Gal Oya Project, Sri Lanka, M.S. thesis, Department of Rural Sociology, Cornell University, 1982, to be published as monograph by ARTI and Cornell RDC.

6. This was suggested by our Cornell colleague, Professor Randy Barker, based on work done previously on water management at the International Rice Research Institute in the Philippines.

7. The index can be expressed in the following way :

WAI = (a x 1) + (b x 2) + (c x 3) + (d x 4) + (e x 4), where

a = number of days of severe shortage within critical growth period;
b = number of days of moderate shortage within critical period;
c = number of days of saturation within critical period;
d = number of days of standing water within critical period; and
e = number of days of flooding (running water) within critical period.

(d) and (e) were weighted the same since water supplied to the plant is essentially the same; differences in aeration cannot be readily quantified.

8. The calculation of the Water Problem Index can be illustrated by showing the figures for D-channel areas in units 23 and E, those with the lowest and highest WPI, indicating the least and the most severe water problems :

	Shortage of Water		No Water		
Per cent Responding	Maha	Yala	Maha	Yala	
Unit 23	10%	37%	0%	0%	
Unit E	5	39	79	100	
WPI Weighting Factor		x2	x2	x4	
WPI Calculation					
Unit 23	10	74	0	0	= 84
Unit E	5	78	158	400	= 641

Enumerators' acceptance of multiple responses could blur the extent of shortage of water somewhat, since farmers could report both shortage and lack of water for different times of the season. Even so, the index derived seems to reflect degrees of water problems within the Left Bank system rather well, since it is supported by several years of observation by ARTI staff. For elaboration on the survey and index, see Wickramasinghe, "Farmers' Perceptions of Water Problems and Their Resulting Behaviour," and Uphoff and Wickramasinghe, "Implications of Farmers' Perception of Water Problem Severity for Problems of Water Management : Methodology for a Water Problem Index and Attitudinal Analysis," in 1980 Yearbook cited above.

9. Since these were depth readings, they cannot be interpreted directly in volumetric terms. Given the greater difficulty in obtaining the latter, it was decided to settle for information on flows (on-off, and relative depth from a fixed point in the channel). Efforts are being made currently to convert this into volumetric information. Even though the y axis is not standardized, the relative increases and decreases in deliveries, as well as their length and timing, can be seen from the figures.

10. Unit 3 was included in the original ARTI analysis as a "middle" unit, but for reasons discussed below, its water situation is much better than many units geographically more toward the head, and its yields are among the highest in the Left Bank, so considering it here as "middle" makes little sense. Also, since 10 and 14 are

served by distributaries M16 and M18 respectively, it might seem that they are locationally rather similar. In fact as seem from the Map in Figure 1, and the data in Table 1, they are locationally and hydrogeologically quite different.

11. This analysis has been done by Svensen and Wijayaratne in a paper, "The Spatial Distribution of Irrigation Water and Yields on the Gal Oya Left Bank", to appear in Sri Lanka Journal of Agrarian Studies, 1982.

12. "Managing the Main System : Canal Irrigation's Blid Spot", Economic and Political Weekly, XV:39, September 1980.

13. These problems are explored in Murray-Rust, "Hydrological Conditions in Gal Oya L.B. Command Area : Preliminary Findings and Implications", in 1980 Yearbook, op. cit.

14. An analysis by Murray-Rust, ibid., found that the supply of water to field channels appeared to be largely a function of the number of channel bifurcations between the field channel and the top of the D-channel system. Simple distance from the head of the D-channel and the number of intermediate farm pipe inlets, while having some relationship to the water flow, appeared less significant.

15. See Uphoff, Wickramasinghe and Wijayaratne, "'Optimum' Participation in Water Management : Issues and Evidence from Sri Lanka," paper prepared for publication.

16. The problem was raised in Chambers' paper cited in footnote 4, which suggested that farmers would not want to have a committee form a decision-making when there were water problems, but would prefer to have a single authoritative decision-maker like the vel vidane

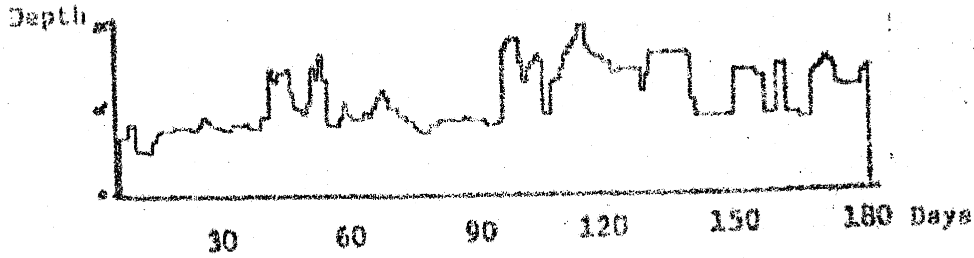
17. The function used was $Y = a + bx^2 - cx^4$, where Y = preference for farmers' council, and x = WPI for that unit.

18. This issue and this dynamic are gone into in some detail, using Gal Oya as well as other Sri Lankan data, by Mick Moore et al, in a very instructive paper, "Space and the Generation of Socio-Economic Inequality on Sri Lanka's Irrigation Schemes", Marga Journal, (forthcoming).

DEPTH OF FLOW IN UNIT 2 (HEAD) CHANNEL SYSTEM - Maha 1979/80

FLOW IN LEFT BANK MAIN CANAL AT LB 6 DISTRIBUTARY

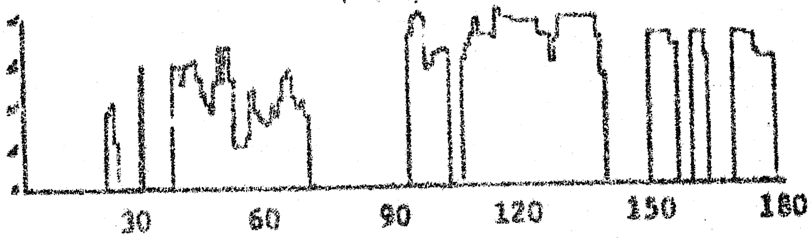
Figure 1-M



FLOW IN LB 6 DISTRIBUTARY

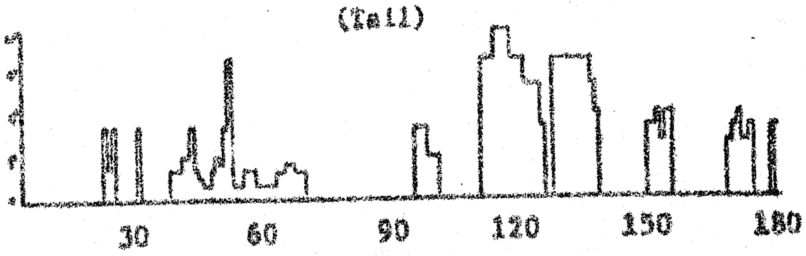
(Head)

Figure 1-DH



(Tail)

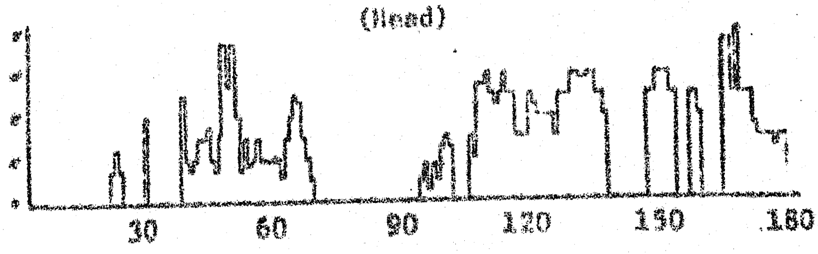
Figure 1-DT



FLOW IN LB 6-1 FIELD CHANNEL

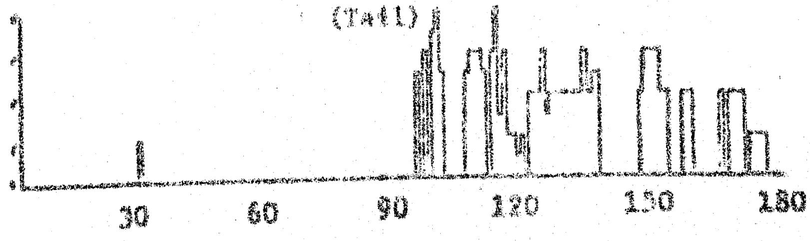
(Head)

Figure 1-F-1H



(Tail)

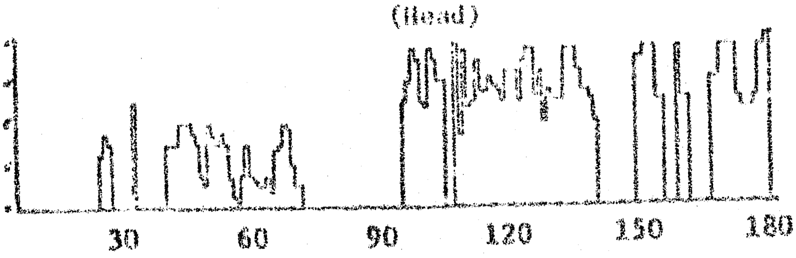
Figure 1-F-1T



FLOW IN LB 6-4 FIELD CHANNEL

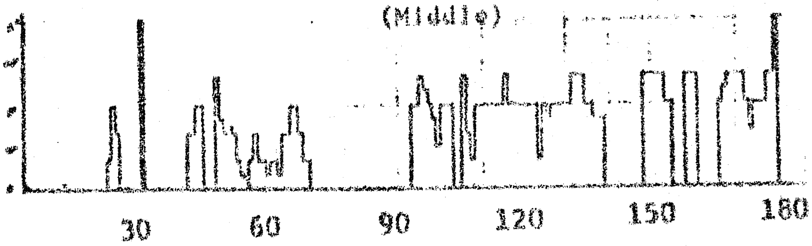
(Head)

Figure 1-F-2H



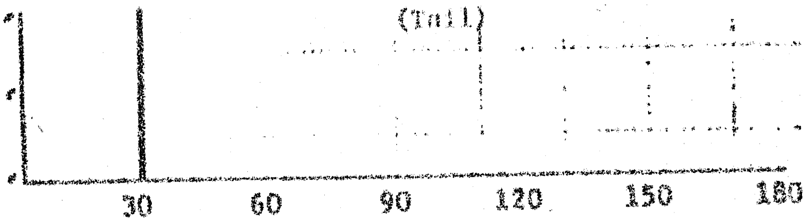
(Middle)

Figure 1-F-2M



(Tail)

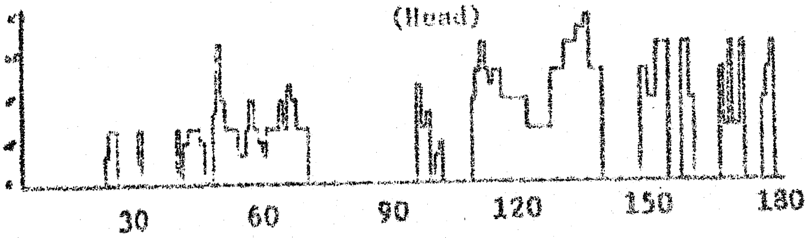
Figure 1-F-2T



FLOW IN LB 6-5 FIELD CHANNEL

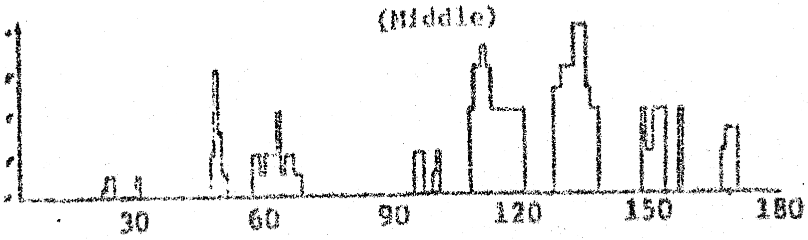
(Head)

Figure 1-F-3H



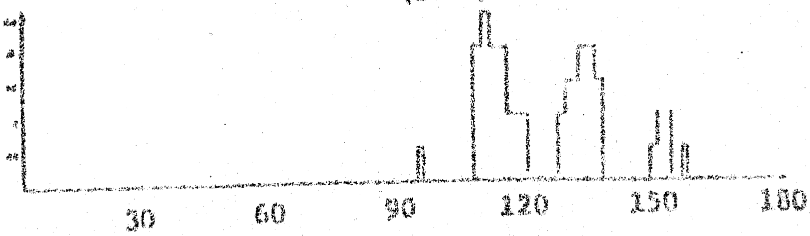
(Middle)

Figure 1-F-3M



(Tail)

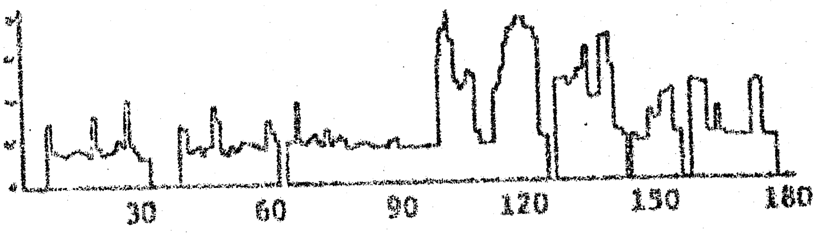
Figure 1-F-3T



DEPTH OF FLOW IN UNIT 21 (HEAD) CHANNEL SYSTEM - Maha 1979/80

FLOW IN UHANA BRANCH CANAL AT DISTRIBUTARY UB 9 *

Figure 2-M



*Unit 21 is at the head of the Uhana Branch sub-system, which is at the head of the Left Bank system overall.

FLOW IN UB 9 DISTRIBUTARY

Figure 2-DH

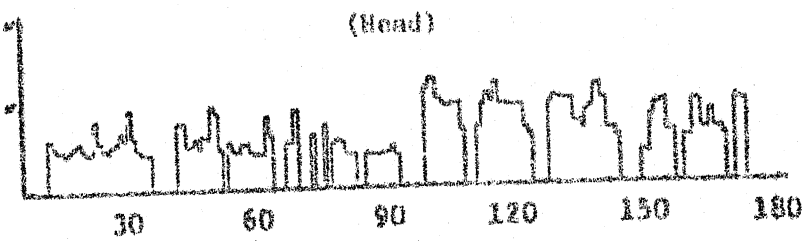
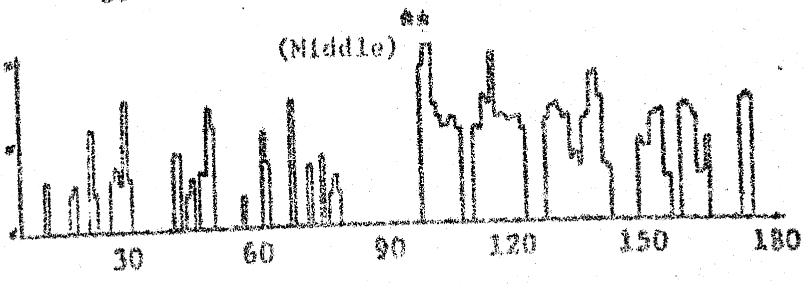


Figure 2-DM

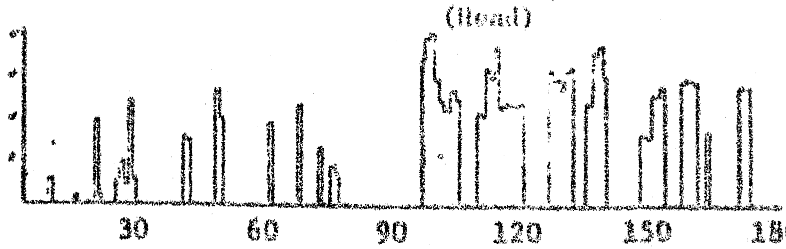


**These measurements taken at the distributary where it left the area of Unit 21 represent the middle rather than the tail of UB 9 D-channel. The differences in height indicated on the Y axis do not signify actual differences in volume because channel width was not standardized; differences in flow can be seen from the frequency of flow and the variation between peak and typical flow levels.

FLOW IN UB 9-2 FIELD CHANNEL

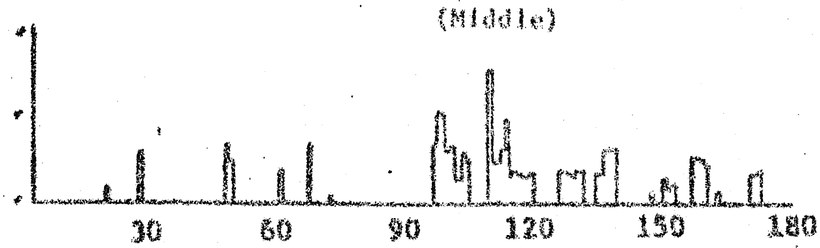
(Head)

Figure 2-F-1H



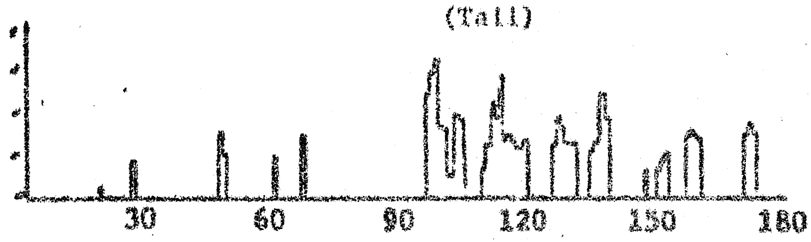
(Middle)

Figure 2-F-1M



(Tail)

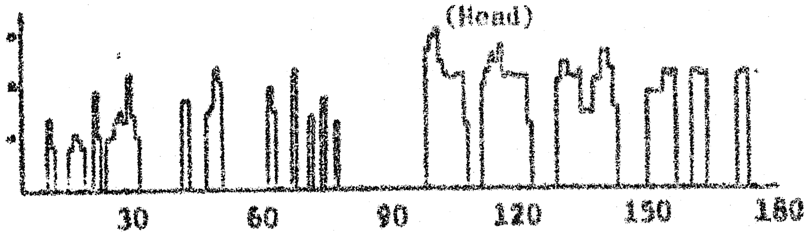
Figure 2-F-1T



FLOW IN UB 9-4 FIELD CHANNEL*

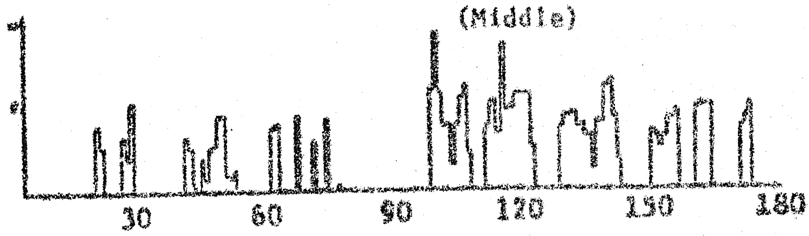
(Head)

Figure 2-F-2H



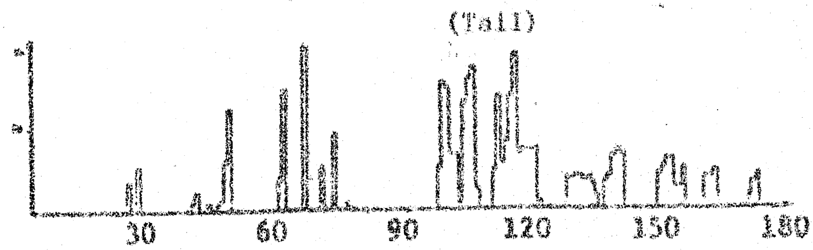
(Middle)

Figure 2-F-2M



(Tail)

Figure 2-F-2T

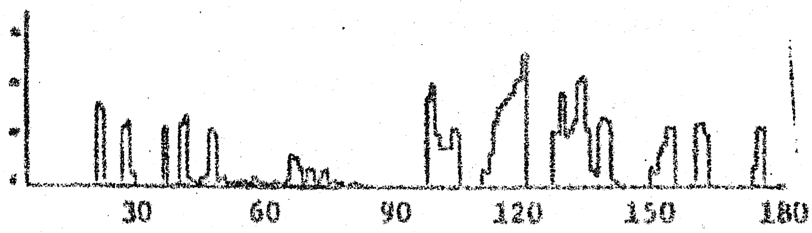


*This is a middle rather than a tail field channel within UB 9 system.

DEPTH OF FLOW IN UNIT 8 (MIDDLE) CHANNEL SYSTEM - Maha 1979/80

FLOW IN MANDUR BRANCH CHANNEL AT M 5 DISTRIBUTARY

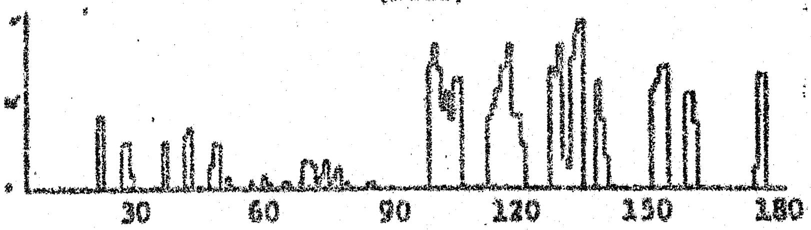
Figure 3-M



FLOW IN M 5 DISTRIBUTARY

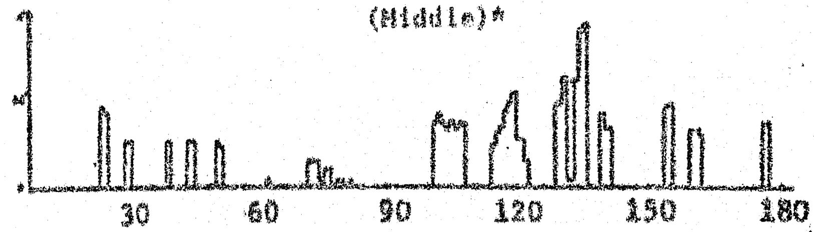
(Head)

Figure 3-DH



(Middle)*

Figure 3-DM

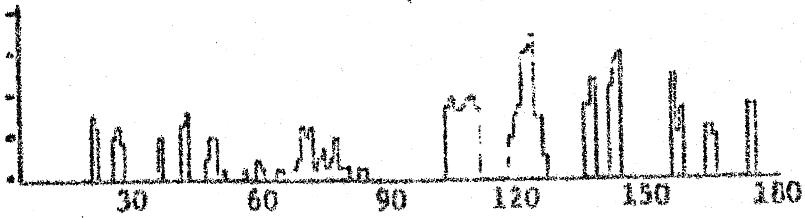


*This distributary also flows farther beyond Unit 8, so the measuring point should be seen as representing a middle more than a tail position in the D-channel system.

FLOW IN M 5-2-1 FIELD CHANNEL

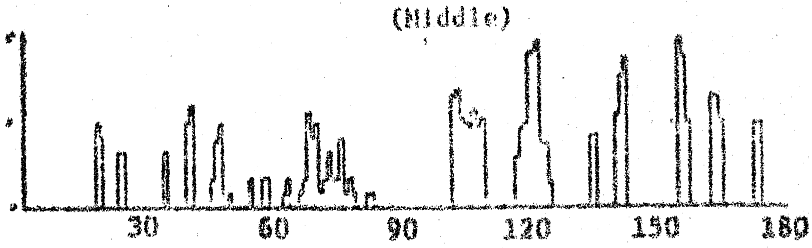
(Head)

Figure 3-F-1H



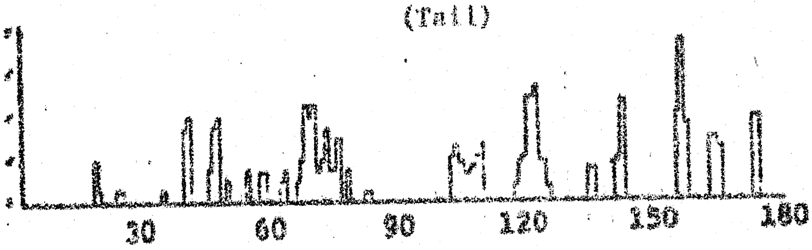
(Middle)

Figure 3-F-1M



(Tail)

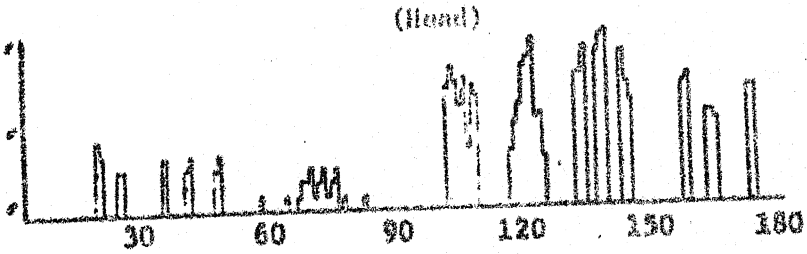
Figure 3-F-1T



FLOW IN M 5-2-4 FIELD CHANNEL

(Head)

Figure 3-F-2H



(Middle)

Figure 3-F-2M

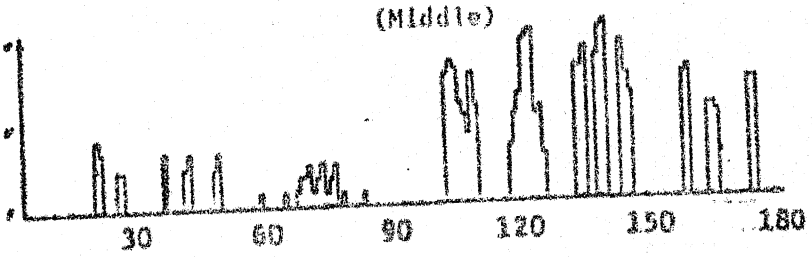


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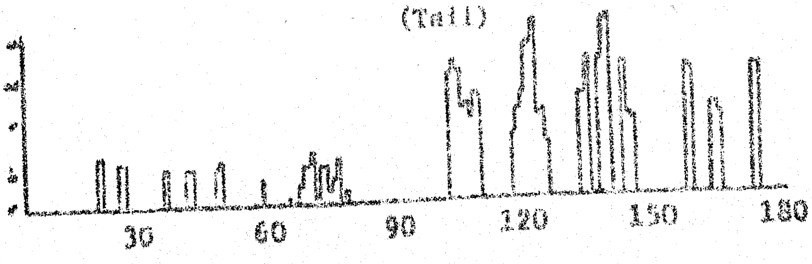
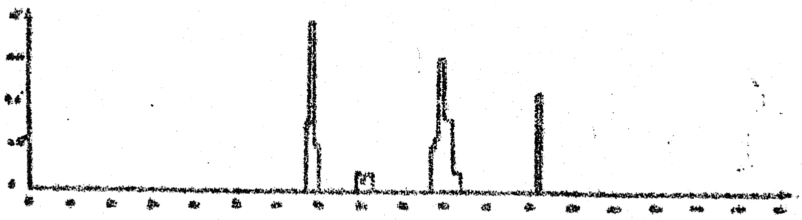
Figure 3-F-2T



DEPTH OF FLOW IN UNIT 7 (TAIL) CHANNEL SYSTEM - Maha 1979/80

FLOW IN MANDUR BRANCH CANAL AT M 18 DISTRIBUTARY

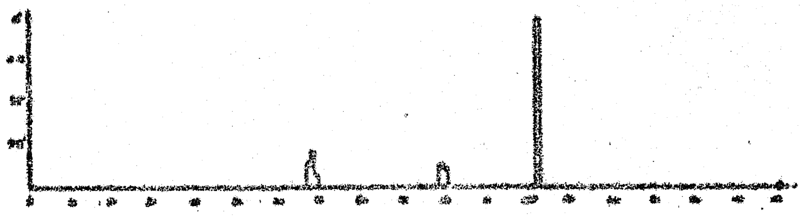
Figure 4-M



FLOW IN M 18 DISTRIBUTARY

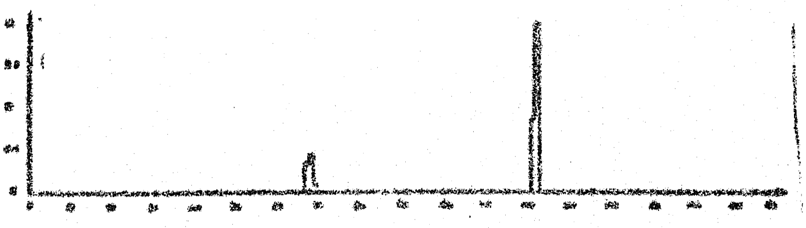
(Head)

Figure 4-DH



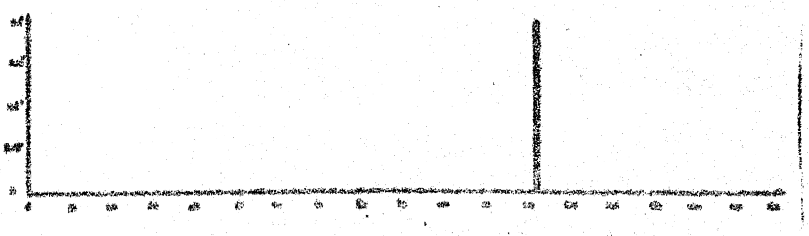
(Tail)

Figure 4-DT



FLOW IN M 18-1-6-2 FIELD CHANNEL

Figure 4-F



6

DIFFERENTIAL INCOME IMPACT OF PUBLIC CANAL IRRIGATION IN MAHARASHTRA*

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1. Objective

The two-fold objective of this note is (a) to measure the magnitude of increase in farm incomes due to public canal irrigation and (b) to assess the extent to which these income increases bear positive association with farm size. The analysis is based on two recent sample surveys of farms receiving canal water from two newly-established major irrigation projects in Maharashtra, namely, Girna Project in Jalgaon District and Ghod Project in Ahmednagar District.[1] The survey data pertains to 1975-76, a normal agricultural year in the post-HYV period. The command areas of the two projects differ in respect of farm conditions which permits a comparative analysis as well.[2] However, our primary interest is in the differential income impact of public irrigation on marginal, small, large and big farms.

2. Conceptual and Methodological Issues

Since the authors of the survey reports have not attempted to measure the impact of irrigation on farm incomes, our first task is to reanalyse the data to arrive at reliable estimates of incremental income due to application of irrigation water to a hectare of crop area.[3] The endeavour here is to improve upon the conventional method in which one first estimates the average incomes for an unirrigated crop hectare

* This note is a part of the author's larger study, entitled Impact of Irrigation on Farm Economy, which is still in progress.

and an irrigated crop hectare, and then takes the difference of the two as a measure of incremental income due to irrigation. While we do follow the same underlying approach, we apply the with-and-without-irrigation analysis to different crop groups distinguished on the basis of crop season. As is shown elsewhere,[4] this modification eliminates the underestimation of income impact of irrigation inherent in the conventional method.

The survey reports cover many irrigated and unirrigated crops, for each of which three separate figures of income are given, namely, (1) farm business income on Cost A basis, (2) family labour income on Cost B basis, and (3) net income on Cost C basis. These three cost concepts were evolved in the course of the Farm Management Studies in India. Since Cost C is the most comprehensive in coverage - in the sense that it includes imputed costs of all family or farm supplied inputs of agriculture - income impact based on increase in net income appears more suitable for our purpose. However, two limitations need to be pointed out.

First, cost imputations at uniform prices for capital and labour inputs for all categories of farmers can distort benefits from irrigation. More specifically, one may end up overstating marginal and small farmers' benefits by assuming interest rates for fixed and working capital to be nearer the institutional rates which is truer for large and big farmers having better access to institutional funds and whose opportunity cost of accumulating own capital is much less than that of small and marginal farmers.[5] No doubt, the opportunity cost of family labour (and to a large extent of bullock labour) may be much less for the marginal and small farmers than is reflected by the village hiring rates employed in the valuation of such labour. But how these two biases counterbalance each other is not possible to assess at this stage of our enquiry.

Second, for the purpose of assessing income impact of irrigation the imputed rental value of land needs special attention, failing which one may substantially underassess the income-augmenting impact of irrigation. This imputation is generally done by assuming a fraction of the gross crop output to be due to land owned by the farmers[6] - in earlier FMS reports the fraction is taken equal to long-term interest rate which is applied to the value of land. Since value of gross output as well value of land rises substantially due to irrigation, the imputed rental value of land in the case of irrigated crops is much higher than that of unirrigated crops. Therefore, rise in rental value of land has nothing to do with land per se i.e. the natural fertility of soil remains unchanged after introduction of irrigation. The case for adducing higher rental value to an irrigated crop hectare arises in two situations : (i) when natural fertility of irrigated areas is known to be superior to that of unirrigated areas in a sample, and (ii) when crop duration of irrigated crops is longer than that of unirrigated crops.

To the extent that the latter situation is encountered in the two sample reports, we may raise the imputed value of land factor in the case of irrigated hectare of crop area in our sample data. In particular one has to take rental value of irrigated crop of banana/adsali sugarcane at twice that of an average unirrigated crop because in growing under irrigation, these 18 month crops a farmer foregoes two unirrigated crops over a two-year period. But no adjustment could be made on account of possible natural superiority of irrigated over unirrigated areas in the two samples. Therefore, our analysis employs both the net income on Cost C basis and the adjusted income for true rental value of land in respect of irrigated crops.

EMPIRICAL RESULTS

3. Incremental Income Impact

The incremental income impact of canal water application to a hectare of crop area turns out to be of the order of Rs.2200 in Girna command area and Rs.1400 in Ghod command area during 1975-76. These estimates are net of irrigation expenditure by the sample of 400 canal beneficiaries contacted by R.G. Patil, et al, in each of the two command areas.[7] On the other hand, when Cost C concept is used without making adjustment in the reported rental value of land, the incremental impact of irrigation diminishes to about Rs.1550 per irrigated ha. in Girna and about Rs.1000 in Ghod.

The estimates of incremental income impact would rise to the extent one were to count as income the increase in imputed cost of family labour due to irrigation. As a result of irrigation, the sample farmers have been able to increase the use of family labour by about 29 labour days in Girna area and 21 labour days in Ghod area. The imputed cost of this additional employment of family labour is about Rs.103 in Girna and about Rs.72 in Ghod area. But these values are not so substantial as to make much difference to the earlier estimates.

Of course, the marginal and small farmers in the two samples may have augmented their income from agriculture to the extent that they offer surplus family labour to other farmers whose demand for hired labour rises in the wake of irrigated farming. Additional payment to hired labour amounts to Rs.143 in the Girna sample and Rs.110 in the Ghod sample as a result of application of irrigation to one crop hectare of area. However, we do not know how this amount is split between landless labourers and marginal/small farmers to determine the additional incomes of the latter. In the samples under study, marginal and small farmers reported substantial dependence on income from hiring their labour services to other farmers. Among the sample marginal farmers, only 14 per cent in Girna command and 18 per cent in Ghod command report complete dependence on their own farms.

4. Canal versus Wells

One may ask : how do the income benefits from canal irrigation compare with those from other sources of irrigation, especially well irrigation? In general terms, the benefits from canal irrigation are less than those from well irrigation. The extent of this differential cannot be ascertained in the present case as we do not have comparable estimates for well irrigation for the year 1975-76. However, an indirect comparison is possible by adopting the following approach, whereby benefits are computed in terms of grain equivalents, and not in value terms. That is, by dividing the value of benefits by the price of a certain grain, say jowar, one converts these benefits into physical units which permit comparison of benefits over time during which prices may have risen. In terms of local jowar equivalents, the incremental income impact in Ghod turns out to be about 7.66 quintals (on Cost C basis) for every hectare of irrigated area. The corresponding figure for well irrigation based on FMS data for Ahmednagar district for the period 1969-70 to 1971-72, is about 9.12 quintals.[8] Thus, on Cost C basis an irrigated hectare under well irrigation in Ahmednagar district generates about 20 per cent more income than the one by canal irrigation.

For Jalgaon district, Renu Bala has assessed that application of well water to a hectare of crop area in Upper Tapi (Hatnur) Irrigation Project yielded an income increase of the order of Rs.4400 during 1977-78.[9] This is almost twice the level of our own estimate for Girna canal area. However, this income differential between well and canal irrigation is overstated for two reasons. First, the concept of income used in Upper Tapi Irrigation Project report prepared by the Administrative Staff College of India, Hyderabad, is one based on paid out costs only. Secondly, the price level during 1977-78 was somewhat above that of 1975-76, the year to which Girna sample relates. For example the price of jowar is mentioned to be in the range of Rs.125-175 per quintal in Upper Tapi sample as against Rs.130 in the Girna sample.

5. Between Two Commands

Since rainfall conditions in Girna command area far more favourable for dry farming than in Ghod command,[10] one would expect that, other things being equal, irrigation benefits in the former area should be less than those in the latter area. However, the results are contrary to this expectation, indicating thereby that 'other things' must be far from being alike in the two samples. More specially, the 'other things' appear to be tilted in favour of Girna farmers. It is not the intention here to enumerate these innumerable factors which impinge on farm productivity, nor to size them up in terms of their differential impact on the two samples of farmers. Instead, we may consider these factors with a view to identifying only those that enhance the impact of irrigation on farmers' income.

Numerous studies on irrigation have underscored the importance of crop pattern changes in enhancing the impact of irrigation on farm income in particular and rural farm economy in general. From this perspective, the irrigated crop pattern in Girna command sample turns out to be indeed more remunerative than that observed in Ghod sample. Thus, sugarcane and banana, the two most remunerative crops of irrigated farming in Maharashtra, are proportionately greater in Girna irrigated farming than in Ghod area. As against 10 per cent of gross irrigated area being under sugarcane in Ghod sample, the combined share of sugarcane and banana crops is over 15 per cent in Girna sample. Additionally, chillies, another remunerative crop next to sugarcane and banana, constitutes 4.5 per cent of irrigated crop pattern in Girna compared to 0.2 per cent in Ghod sample.

Why have sample farmers in Ghod area not been able to adopt as remunerative a crop pattern as in the Girna area? It may partly be due to the fact that irrigation availability to them is not so good as in the other command area. It may also be due to other factors, such as poorer access to metropolitan

market of Bombay where perishables like bananas and vegetables are much in demand. On the whole, only one-eighth of the Girna farmers complained of various difficulties regarding irrigation, while as many as two-thirds of the farmers did so in Ghod. Since crops requiring heavy irrigation throughout the year cannot be grown without perennial supplies of water, from the viewpoint of perenniality of irrigation, Girna sample farmers are better placed, with 30 per cent of their irrigation being of perennial nature as against 16 per cent of the available irrigation being perennial in Ghod command sample. Further, from the viewpoint of control over the sources of irrigation, the Girna farmers are more advantageously placed. Their dependence on public canals is of the order of two-thirds as against three-fourths in Ghod sample. Possessing one's own means of irrigation, in addition to canal irrigation, improves one's capacity to do timely irrigation, which is so necessary for HYV farming. The considerable difference in the share of wheat, hybrid jowar and hybrid bajra in the two samples may partly be due to the difference in the control over sources of irrigation.

Among other factors, better access to metropolitan markets in the case of Jalgaon sample may explain why their income benefits are higher. For example, in the case of wheat crop, the Girna farmers report a price realisation of Rs.150 per quintal of wheat as against Rs.134 per quintal in the case of Ghod farmers. Other differences among the two samples are of marginal significance in explaining the difference in the impact of irrigation on farm income. In matters of literacy, credit and its sources, incidence of sickness, and social and economic difficulties, the two samples of canal users are fairly similar.

	Ghod sample	Girna sample
1. Literacy (above 5th standard)		
Male	27%	28%
Female	8%	12%
2. Credit per ha.	Rs.1961	Rs.1790
3. Share of institutional credit	82%	76%
4. Family members affected by sickness during 1975-76	13%	9%
5. Social and economic difficulties	49%	42%

6. On-Farm Benefits and Farm Size

Notwithstanding the larger income impact of irrigation in Girna than in Ghod command, the income benefits from a crop hectare of irrigated area are found to be positively associated with farm size. This size-wise differential impact of irrigation on farmers is best expressed in terms of an index of relative benefits where the income benefits of big farmers (about 8 hectares) are assumed to be equal to 100. The index numbers of these relative benefits in Ghod and Girna commands are listed in Table 1. In Ghod sample, the marginal farmers with average farm holding of 1.25 ha., realise half as much benefits as do the big farmers with average farm holding of over 11.50 ha. The small farmers fare better than the marginal farmers, but with their benefit level being about three-fourths of the big farmers' level. Medium or middle farmers with farm holdings of about 5 hectares perform still better than small farmers, their benefits being only one-sixth less than that of big farmers. But it is the large farmers operating about 7 hectare farms that turn out to be the highest gainers, with benefits slightly above the level of the big farmers (vide Table 1).

Table 1 : Index Numbers of Income Benefits due to a Crop Hectare of Irrigated Area in Girna & Ghod Commands, 1975-76 (Big Farmers' Benefits = 100)

Sl. No.	Farmer Category According to Size of holding	Girna Command Area		Ghod Command Area	
		This Author's basis of costing	On Cost C basis	This Author's basis of costing	On Cost C basis
1.	Marginal farmers (less than 2 ha.)	60	57	53 (54)	50 (50)
2.	Small farmers (2 - 4 ha.)	87	85	76 (76)	75 (74)
3.	Medium farmers (4 - 6 ha.)	83	82	86 (85)	84 (83)
4.	Large farmers (6 - 8 ha.)	87	85	104 (106)	101 (103)
5.	Big farmers (above 8 ha.)	100	100	100 (100)	100 (100)

Note : Index numbers within brackets are based on the assumption that kharif unirrigated farming is not feasible.

The marginal and the small farmers in the Girna sample, though realising considerably much less benefits than those accruing to big farmers, are not as worse off as in the Ghod sample. Moreover, between farm sizes of 2 and 8 hectares, the benefits are not related with farm size. The source of the relationship between farm size and farm incomes under conditions of irrigation becomes clearer from looking at the quality of irrigation available to each category of farmers.

Marginal and small farmers in both the samples, as compared to the large and big farmers, realise smaller net output from their irrigated farming, indicating lesser use of productive inputs like chemical fertilizers, hybrid seeds, pesticides, etc. In Girna sample, their incremental set-up in the cost of chemical fertilizers due to irrigation is about seven-tenths of that

achieved by the big farmers. In physical terms, i.e., sum total of nutrients (N, P and K), the incremental step-up of small farmers is hardly four-fifths of that of the big farmers. The increasing use of chemical fertilizers in Girna sample is strongly associated with farm size. A similar association exists in the Ghod sample, with the notable exception that large farmers with 6-8 ha. holdings report the maximal step-up in fertilizer application. This group of farmers, as already noted, also realises the maximum benefits in the shape of incremental income.

The increasing use of chemical fertilizers with farm size can be explained by a variety of factors : remunerativeness of irrigated crop pattern, quality of irrigation, credit availability, etc. These are observed to be positively related with farm size (vide Tables 2 and 3). Of these, quality of irrigation is the most dominant determinant because use of chemical fertilizers in low rainfall areas, like that of Ghod or Girna command, is complementary with irrigation whose quality has a strong bearing on the choice of crop to be grown.

There are of course many more factors positively associated with farm size, thereby increasing the income impact of irrigation with the increase in farm size - for example, literacy, health and access to agricultural information. Likewise, many constraining factors diminish in intensity with increase in farm size - e.g. availability of drinking water, caste disabilities, problems with gram panchayat, etc. Quantitative information about such variables for different size class of farmers provides many clues to the farm size-income benefit relationship in the wake of irrigation.

Table 2 : Comparative Statistics of Farm Size Classes in Girna Sample 1975-76

Sl. No.	Statistic	Marginal farmers	Small farmers	Medium farmers	Large farmers	Big farmers	All Sample farmers
1	2	3	4	5	6	7	8
1.	Number of sample households	159	106	60	31	44	400
2.	Average farm size (ha.)	1.27	3.18	5.01	6.46	11.66	3.88
3.	Index number of income benefits due to a crop hectare of irrigated area	60(57)	87(85)	83(82)	87(85)	100(100)	
4.	Index number of incremental step-up in chemical fertilizers due to irrigation (N+P+K terms)	72	77	78	86	100	
5.	Quality of Irrigation Available						
	a. perennial irrigation as % of total irrigation	28	34	23	33	32	30
	b. per cent contribution from wells	11	17	31	45	28	26
	c. per cent farmers in a size class reporting difficulties regarding irrigation	13	12	12	10	7	12
6.	Remunerativeness of Irrigated Crop Pattern						
	i. per cent irrigated area under banana	5.3	11.3	15.7	11.5	14.1	11.8
	ii. per cent irrigated area under sugarcane	3.3	1.8	1.5	4.6	7.2	3.7
	(i) + (ii)	8.6	13.1	17.2	16.1	21.3	15.5
7.	Credit Availability						
	a. per cent farmers in a class reporting credit difficulties	44	42	32	26	16	37
	b. percentage of credit obtained from government and credit institutions	64	73	78	76	80	76

Table 2 (contd.)

1	2	3	4	5	6	7	8
8.	Access to Information about Argri-cultural Practices (%)						
	a. for all sources of communication**	15	17	23	33	37	21
	b. radio	5	8	18	45	45	16
9.	Extent of Education Above 5th Class						
	i. males (%)	22	23	34	29	45	28
	ii. females (%)	6	11	14	20	20	12
10.	Other difficulties affecting farm productivity						
	i. sickness (% family members)	11	10	10	7	5	9
	ii. drinking water (% farmers in a class)	74	80	80	71	66	76
	iii. castism (% farmers)	23	22	13	10	7	18
	iv. problem with gram panchayats(%)	20	24	15	13	7	18
11.	Value of implements and machinery per hectare of farm holding (Rs.)	384	638	714	721	548	601

Notes : 1. Index numbers are computed by putting big farmers' value of a parameter = 100.

2. Figures in brackets result when cost C is deducted from gross output.

** Nine sources of communication are considered : radio, training camps, exhibitions, film shows, meetings, demonstrations, educational tours, 'melvas' (farmers' rallies) and printed material (including newspapers).

Table 3 : Comparative Statistics of Farm Size Classes in Ghod Sample 1975-76

Sl. No.	Statistics	Marginal farmers	Small farmers	Medium farmers	Large farmers	Big farmers	All farmers
1	2	3	4	5	6	7	8
1.	Number of sample households	128	110	65	42	55	400
2.	Average farm size (ha.)	1.25	2.94	4.95	7.20	11.48	4.35
3.	Index number of income benefits due to a crop hectare of irrigated area (big farmers = 100)	54(50)	76(74)	85(83)	106(103)	100(100)	
4.	Index number of incremental step-up in chemical fertilizers due to a hectare of irrigation (big farmers = 100) (N+P+K terms)	69	84	100	118	100	
5.	Quality of Irrigation Available						
	a. perennial irrigation as per cent of total irrigation	10	16	18	18	16	16
	b. per cent contribution of wells to total irrigation	20	23	25	27	26	25
	c. per cent farmers in a size class reporting difficulties with regard to irrigation	82	79	48	52	42	67
6.	Remunerativeness of Irrigated Crop Pattern						
	i. per cent area under 'suru' sugarcane	4.2	5.1	4.8	6.0	7.6	5.8
	ii. per cent area under 'adsali' sugarcane	0.9	4.0	3.1	4.6	2.8	3.2
	iii. per cent area under hybrid bajra and hybrid jowar	7.8	5.6	9.8	13.6	7.8	8.6
	iv. per cent area under groundnut, cotton, chillies and vegetables	6.3	8.4	6.6	8.3	7.9	7.6

Table 3 (contd.)

1	2	3	4	5	6	7	8
7.	Credit Availability						
	a. per cent farmers in a class reporting credit difficulties	41	34	34	38	27	36
	b. percentage of credit obtained from government/institutions	82	78	81	87	80	82
8.	Access to Information About Agricultural Practices (%)						
	a. all sources of communication	14	16	21	32	34	21
	b. radio	5	10	22	21	29	14
9.	Extent of Education Above 5th Standard						
	a. Males (% of size class total)	24	26	26	30	30	27
	b. Females (% of size class total)	6	6	6	12	12	8
10.	Other difficulties affecting farm productivity						
	i. sickenss (% family members sick)	16	11	9	12	15	13
	ii. drinking water (% farmers in a class)	88	82	77	71	76	81
	iii. castism	20	18	12	12	11	16
	iv. problem with gram panchayat	27	28	28	26	36	29
11.	Value of implements and machinery per ha. of holding (Rs.)	1022	521	613	567	478	579

Notes : 1. Figures in brackets arise when cost C concept is used.

2. Nine sources of communication, listed in the previous table 2 for Girna command, are involved in item 8 (a).

Since per capita incomes of the sample farmers prior to the advent of canal irrigation in Ghod/Girna commands are not known, a firm analysis of how different size classes of farm families have actually benefited from the introduction of canal irrigation in the two command areas is not possible. However, an indicative analysis of the differential impact has been attempted by estimating per capita incomes of sample farmers during 1975-76, hypothetically assuming that there was absence of canal irrigation. The details of this estimational work are spelt out in Appendix to this note.

As far as income from crop enterprise is concerned, additional per capita income due to canal irrigation too is found to rise sharply with farm size in both Ghod and Girna command areas (vide Table 4).[11] This implies increase in the disparities of income and standard of living between marginal and small farmers on the one hand and large and big farmers on the other. As a matter of fact, the growth of these disparities in the wake of canal irrigation is so substantial that it cannot be bridged by the fact that marginal and small farmers do augment their family income on a greater scale from non-crop enterprises (e.g. earned wages and dairying and poultry). If income differences following from canal irrigation narrow down at all, it occurs in a relative sense, that is, rise in per capita income in percentage terms is inversely related to farm size. Thus percentage rise in per capita net income (on Cost C basis) in Girna turns out to be 246 per cent in the case of marginal farmers, 216 per cent for small farmers, 196 per cent for medium farmers, 146 per cent for large farmers and 163 per cent for big farmers. However, in Ghod there prevails a sort of constancy of per cent income increase over size classes, and this constant relationship turns inverse only when sources of income other than crop enterprise, such as dairy poultry and labour services, are taken into account.

Table 4 : Absolute and Relative Per Capita Income Increase due to Irrigation in Ghod and Girna Commands, 1975-76

Sl. No.	Farmer Group	Girna Command				Ghod Command			
		Absolute Increase		Per cent Increase		Absolute Increase		Per cent Increase	
		On Cost C basis	Our basis	On Cost C basis	Our basis	On Cost C basis	Our basis	On Cost C basis	Our basis
1.	Marginal farmers	Rs. 180	Rs. 292	246	237	Rs. 144	Rs. 214	178	173
2.	Small farmers	Rs. 378	Rs. 619	216	214	Rs. 321	Rs. 461	208	200
3.	Medium farmers	Rs. 536	Rs. 856	196	200	Rs. 468	Rs. 667	193	193
4.	Large farmers	Rs. 553	Rs. 954	146	168	Rs. 732	Rs.1029	175	178
5.	Big farmers	Rs. 919	Rs.1610	163	190	Rs.1020	Rs.1420	200	194
	All farmers	Rs. 436	Rs. 729	188	209	Rs. 455	Rs. 650	190	189

7. Conclusions and Implications

Introduction of public canal irrigation has widened the absolute income differential in the farm sector in Girna and Ghod commands. It has narrowed down between small and big farmers only in a relative sense, that is, in terms of per cent increase in per capita incomes. Thus while the rich has become richer and poor less poor, still their material standards of living, wealth, etc. have become more disparate than before.

Can the widening of absolute income differential be prevented by adopting simply a policy of allocating proportionately more public irrigation resource to small farmers than their share is in land ownership? Such a differential policy in favour of small farmers may narrow only the relative income differentials in the farm sector. Even this may not happen if large farmers manage to realise much greater income benefits from each unit of irrigation water than small farmers. To some extent, the advantage of the farmer stems from scale economies of marketing farm produce and purchasing farm inputs, from indivisibilities of fixed investments, and from risk-bearing capacity, etc. Of course, the large farms may encounter disadvantage in the problem of management, but it is not so serious a matter in the Indian conditions where large holdings are not in fact very large, let alone gigantic.

What really tilts the balance in the matter of income benefits per unit of irrigation water in favour of large farmers is their superior access to all inputs : irrigation, credit, agricultural extension services, bureaucracy, education, communication, medical centres, cooperatives, etc. Some advantage of access to product market may also exist, e.g., large farmers may realise better farm product prices by selling their produce to seed agencies of the state. Small farmers must be enabled to surmount many of these disadvantages. A differential irrigation policy in their favour would serve some purpose of reducing relative income differential in the farm sector, provided the policy is effectively enforced.

APPENDIX

Hypothetical Incomes of Sample Farmers of Ghod and Girna Commands in the Absence of Canal Irrigation

To begin with, hypothetical incomes from crop enterprise alone is estimated, ignoring that from dairy farming, from hiring out family labour to other farmers, from hiring out surplus bullock labour etc. Income from crop production is undoubtedly a major source of income - about three-fourths of the family income of the sample farmers in each command during the reference year 1975-76. Exactly the same proportion is found for Girna command during 1960-61 when Girna project was not in operation. Besides, this proportion rises with farm size (vide Appendix Table 1). Thus wage income of the marginal farmers is an important source of family income, and its exclusion from our hypothetical income estimate may understate the income impact of irrigation on such farmers.

The hypothetical state envisaged is the absence of canal irrigation and prevalence of dry farming. However, some irrigation from other sources did exist prior to the introduction of canal irrigation in these areas. In the case of Girna command the MBES (Maharashtra Bureau of Economics and Statistics) survey of 1960-61 reveals that about 5 per cent of the cropped area benefited from non-canal irrigation, mostly well irrigation. In the absence of canal water, the sample farmers might have made more investments in their own sources of irrigation because of tremendous expansion in long-term credit facilities for minor irrigation between 1960 and 1975. But well irrigation in Maharashtra, according to its Agricultural Census of 1970-71, had not developed on large holdings as much as on small holdings. Thus, well irrigated area as a per cent of net sown area was 16 per cent on marginal holdings in Ahmednagar district, 12 per cent on small holdings (2 - 5 ha.), 10 per cent on 5 - 10 ha. holdings and 9 per cent on 10-20 ha. holdings. Such a differential is not noted for Jalgaon district (see Appendix Table 2).

This may introduce an element of overestimation in assessing hypothetical income benefits from canal irrigation to marginal and small farmers because we ignore their relatively better position in respect of well irrigation had there been no canal irrigation. How far this overestimation is off-set by under-estimation due to leaving out incomes from sources other than crop enterprise is not possible to determine.

Income per unirrigated crop hectare during 1975-76, when multiplied by net cropped area of a farmer during 1975-76, yields a proximate hypothetical estimate of income without irrigation. In other words, it is envisaged that (1) in the absence of irrigation, whatever be its source, the intensity of cropping would be 100 per cent and (2) the net cropped area does not rise as a result of irrigation. Both these assumptions tend to overstate the hypothetical income without irrigation, the overstatement increasing with farm size. Family income with irrigation during 1975-76 is taken to be the same as reported in the two survey reports. Since family size too varies positively with farm size in our samples, inter-class comparison of income gains due to canal irrigation needs to be undertaken in per capita terms. In doing so, family size, expressed in terms of equivalent consumer units in the two reports, is used in our analysis.

Carrying out analysis in terms of net income on Cost C basis, the estimates are shown in Appendix Table 3. If we add to net income the rental value of land, an imputed cost of cultivation, we obtain a more realistic analysis of income impact of irrigation as shown in Appendix Table 4.

APPENDIX TABLE 1

Percentage Shares of a Different Sources of Family Income in Girna and Ghod Samples During 1975-76

Sl. No.	Source of Income	Farmer Category in Girna Command						Farmer Category in Ghod Command					
		I	II	III	IV	V	Whole sample	I	II	III	IV	V	Whole sample
1.	Crop production	55	72	78	76	84	74 (73)	51	68	76	80	82	73
2.	Livestock and poultry	9	16	13	15	10	12 (8)	16	13	13	12	12	13
3.	Wages	18	5	2	neg.	neg.	5 (8)	19	10	5	1	1	6
4.	Business and services	10	4	2	4	3	4	9	6	5	5	3	5
5.	Hiring of implements, animals, sale of trees sale of land, etc.	8	3	5	5	3	5	5	3	1	2	2	3
	All sources	100	100	100	100	100	100	100	100	100	100	100	100

Notes : 1. Neg. stands for negligible (less than half a per cent).

2. Figures in brackets are based on pre-canal bench-mark survey of Girna command conducted by the Maharashtra Bureau of Economics and Statistics (MBES), 1960-61.

APPENDIX TABLE 2

Area Irrigated by Wells as a Percentage of Net Sown Area, Maharashtra State, 1970

District	Size Class of Holding						
	0-2	2-5	5-10	10-20	20-50	50-	Average
Ratnagiri	1.5	0.3	0.3	0.2	0.4	0.2	0.6
Nasik	12.0	9.7	8.2	7.4	5.6	3.9	8.4
Dhule	8.3	7.5	7.9	9.2	7.9	3.9	8.1
Jalgaon	6.9	7.5	8.6	8.9	8.9	4.9	8.1
Bombay Division	5.4	6.4	6.9	7.2	5.5	2.2	6.5
Ahmednagar	15.8	12.1	10.4	9.0	8.2	6.6	10.4
Pune	10.6	8.9	7.6	6.7	4.7	2.3	7.7
Satara	6.5	7.0	7.5	8.0	7.7	3.9	7.2
Sangli	7.7	7.9	7.6	6.9	5.9	3.4	7.4
Sholapur	15.0	9.2	7.6	7.0	6.6	12.1	8.0
Kolhapur	2.8	3.0	2.7	2.1	1.5	0.9	2.7
Pune Division	8.8	8.5	8.0	7.4	6.6	6.3	7.9
Aurangabad	7.3	4.3	3.7	3.4	3.1	4.4	3.8
Parbhani	1.5	0.9	0.8	0.8	0.8	0.5	0.8
Bhir	5.2	3.5	3.2	3.3	3.4	2.8	3.4
Nanded	1.0	0.8	0.8	0.7	0.6	0.7	0.7
Osmanabad	2.8	2.1	2.2	2.4	2.7	3.3	2.4
Aurangabad Division	3.8	2.4	2.2	2.3	2.4	2.8	2.4
Buldhana	0.8	0.9	1.3	1.6	1.8	1.8	1.3
Akola	0.5	0.4	0.4	0.5	0.5	0.4	0.4
Amravati	1.7	1.6	1.7	2.0	1.9	1.8	1.8
Yeotmal	0.4	0.2	0.3	0.6	0.8	0.7	0.5
Wardha	1.6	1.4	1.8	2.2	2.8	3.1	2.0
Nagpur	3.6	2.7	3.1	3.7	4.9	5.3	3.5
Bhandara	0.5	0.6	0.8	1.0	1.5	3.0	0.7
Chandrapur	0.3	0.1	0.2	0.3	0.4	1.3	0.2
Nagpur Division	1.0	0.9	1.1	1.4	1.7	1.7	1.2
STATE	5.1	4.5	4.2	4.0	3.5	3.3	4.2

APPENDIX TABLE 3

Estimated Net Income (on Cost C Basis) in the Absence of Canal Irrigation and Actual Income With Canal Irrigation During 1975-76 in Girna and Ghod Command

Farmer Category	Girna Command Sample				Ghod Command Sample			
	Unirrigated crop area per farmer (ha)	Net income per unirrigated (ha) (Rs)	Estimated per capita income under unirrigated farming* (Rs.)	Reported per capita income* (Rs)	Unirrigated crop area per farmer (ha)	Net income per unirrigated ha* (Rs.)	Estimated per capita income from unirrigated farming* (Rs)	Reported per capita income* (Rs)
I	1.19	357	73	253	1.11	390	81	224
II	2.91	396	175	552	2.69	363	154	475
III	4.55	470	274	810	4.30	423	242	710
IV	5.48	576	378	931	6.21	495	418	1149
V	9.72	532	566	1485	9.05	404	510	1530
Sample	3.42	467	232	668	3.59	419	240	695

* Income from crop production alone is considered.

APPENDIX TABLE 4

Estimated Net Income (Including Rental Value of Land) Without Canal Irrigation and Observed Income with Canal Irrigation During 1975-76

Farmer Category	Girna Command Area				Ghod Command Area			
	Unirrigated crop area per farmer (ha.)	Net income per unirrigated farming ha. (Rs)	Estimated per capita income under unirrigated farming (Rs)	Observed per capita income (Rs)	Unirrigated crop area per farmer (ha.)	Net income per unirrigated ha. (Rs.)	Estimated per capita income under unirrigated farming (Rs.)	Observed per capita income (Rs.)
I	1.02	599	123	415	0.38	599	124	338
II	2.18	653	289	908	0.92	541	230	691
III	3.14	733	428	1284	1.43	605	346	1013
IV	4.19	867	569	1523	3.04	684	577	1606
V	8.49	798	849	2459	4.35	579	731	2151
Sample	2.72	700	348	1077	1.52	601	344	994

Footnotes

1. R.G. Patil, S.D. Suryawanshi and P.M. Kapase, The Socio-Economic Survey of Girna Irrigation Project Area in Jalgaon District (Maharashtra) and An Investigation into Socio-Economic Conditions in Ghod Command Area (Maharashtra), Department of Agricultural Economics, Mahatma Phule Krishi Vidyapeeth, Rahuri, The Girna Report was published in 1978 and the Ghod Report in 1980.

2. The survey design of the two studies is the same, as are the concepts and the presentation of survey results.

3. A hectare of crop area is not to be confused for a hectare of land area.

4. B.D. Dhawan, "Assessing Impact of Irrigation", Institute of Economic Growth, Delhi, September 1981 (mimeo).

5. While interest on working capital is imputed at the rate of 13 per cent for all sample farmers in the two survey reports, interest of fixed capital is reckoned at 9 per cent.

6. Rental value of owned land is taken equal to one-sixth the gross produce of a crop in the two studies.

7. The apparent expenditure on irrigation, as reported in the two studies, averages Rs.230 per hectare in Girna and Rs.175 in Ghod. Since these expenditures are not inclusive of irrigation costs in the shape of (1) use of human and bullock labour in irrigation activity and (2) interest and depreciation on fixed assets used for irrigation purpose, these are not to be contrasted with income benefits of irrigation with a view to ascertaining farmers' private benefit-cost ratio for irrigation.

8. This estimate is worked out by the author. The corresponding estimate, based on Cost A basis, is presented in another study by the author, namely, Dugwells in Maharashtra Agriculture, Institute of Economic Growth, Delhi, September 1981

9. Renu Bala, "Measurement of Income Benefits from Well Irrigation in Jalgaon District of Maharashtra", Institute of Economic Growth, Delhi, October 1981 (typescript).

10. The comparative rainfall in the two command areas during 1975 was as follows :

Girna Command		Ghod Command	
1. Amalner	1276 mm	1. Karjat	624 mm
2. Bhadgaon	1143 mm	2. Shrigonda	552 mm
3. Chalisgaon	747 mm	3. Shirur	662 mm
4. Erandol	748 mm		
5. Parola	807 mm		

11. This has happened despite an inverse relationship between irrigation and farm size. Gross irrigated area as a percentage of farm size of holding varies across size class as follows :

	Girna Command	Ghod Command
i. Marginal farmers	81	92
ii. Small farmers	56	77
iii. Medium farmers	61	71
iv. Large farmers	53	60
v. Big farmers	45	53
All farmers	56	66

7

A Study on Equity and Productivity in Periyar-Vaigai Irrigation System-Madurai, Tamil Nadu

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Introduction

Basic to all discussions on welfare implications of irrigation projects are issues of equity and productivity as means to achieve ends of maximum social benefits or welfare, ultimately. While debates on operationalization of concepts of equity and maximum social welfare are still unresolved, certain broad consenses seem to be available. More explicitly, we may define equity in the context of many reference issues, relate it to productivity and then on to distributional implications on efficiency and welfare. This will be our approach in this paper.

Conceptual Issues

Consider, first, concept of equity. It has two dimensions. First, it defines how irrigation water in the system is distributed and on what criteria it is based. Second, how differentials in productivity are narrowed down without reducing its upper bound. It implies realization of system efficiency at a higher levels. Considering these two, the former may be termed as access equity while the latter can be productivity equity.

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These are stylized factors of irrigation distribution and development and under ideal conditions they complement each other. Given this broad classification we may examine each one of them in turn regarding its relation or linkage with policy issues.

Access equity implies that water users of an irrigation system have equal, unconstrained opportunities to utilize water available through distribution. The question really is, what do we mean by equity and access equity in particular? Does it mean equal sharing of available water on prorata basis in proportion to - acreage or size of farms?, location and reach of water without conveyance losses? What are norms one would like to have for maximum access equity? There can be many more inconvenient questions social scientists may raise to the chagrin of system engineers and designers. While there can be some semblance of consensus atleast among social scientists, perspectives differ widely and quite significantly between social scientists and engineers.

Considerations of system efficiency for maximum output may be technical and operable which may run in conflict with considerations of distributional implications. Much of the controversies can be cleared if one could be careful to define equity not merely in terms of distribution of water resources but also for realizing maximum benefits and higher productivity of water. This becomes then a technical problem and distribution of water is system determined. Accordingly, there are tailenders and upenders with expectations to receive certain quantity of water from the system. Note that this does not imply equal distributions but a pattern decided by technical considerations such as lay of fields and channels and extent of conveyance losses. Management problems are different and arise only when these norms of equity are violated. When water users, whether at tail-end or upper end, do not receive what they are entitled.

Now it is easy to define access equity in terms of entitlement and it may be seen that access equity has technical basis. It is not what and how water users should have access to equal share but access to their entitlement determined technically by the system. Perhaps one may think of alternative systems for different degrees of access equity and decide politically what system should go in. This involves efficiency consideration which will discuss shortly but the fact remains that once choice of a system is made, entitlement or access equity for the system gets determined and what remain then are management problems.

Efficiency is realisable through sound management of system (O&M) and optimum utilization of water and its cooperant factors at farm level. We will confine our discussions to the first factor. Before that a digression on choice of a system. There are political compulsions to go in for a particular system design which by comparison may not be the most efficient technically. There can also be economic justification for this choice on the basis of wider incidence of prosperity, less variability and more opportunities for the havenots. Some considerations of trade off between efficiency and welfare are involved and decisions on a system depends upon economic and political considerations. Given this, productivity and efficiency are management issues requiring appropriate operations and management planning and strategies.

For achieving an efficient management system for distribution of water and maintenance of distribution structures, involvement of department of irrigation and local institutions in distribution and use of water would be necessary. There are methods and procedures of distribution of water evolved historically over years and this go under the riparian rights of the farmers involved. There are also formal and informal irrigation societies which are directly managing irrigation at the level down below main canal. Their institutions are also evolved

over years and their modus operandi are based on social considerations in the past. Recently, there are evidences to show that the so called agreed methods are questioned by farmers who have acquired political strength. This has created problems in management of irrigation system at the field level. However, there are non-formal institutions which are dynamic in the sense that social changes are being brought into management methods and procedures, where the friction seems to be very much less. The potential of these institutions is great in this difficult area and one should try to exploit this by restructuring the existing institutions to extent possible, keeping always in mind that there is some trade off between efficiency and equity. In sum we may state that equity in water distribution involves rights of entitlement for water and so long this rights are not violated the equity or more precisely the excess equity is achieved by the system. Secondly the productivity equity which of the results of operation and management of the system would also be maximum if institutions, both formal and informal, are involve in developing a state of operation and management strategies consistant with the over all social welfare goals. In what follows a case study on equity and productivity in Periyar and Vaïgai Irrigation system is presented.

The Periyar-Vaigai irrigation system, one of the largest irrigation systems in Tamil Nadu was conceived in the year 1898 and a dam of 427 meter long and 48 meter high was constructed to arrest the flow of water which originated from the Western slopes of the Western Ghats at an altitude of 1500 meter above M.S.L. in Kerala State and the entire water got drained into Arabian sea without any use. This is called Periyar lake the water from this lake is diverted eastwards through four pen-stock pipes into Tamil Nadu State. The water is used to generate electricity and then drained into the river Viravanar which is a tributary to the Vaigai river system.

The river in its course normally benefits 1,69,280 acres in Madurai and Ramanathapuram districts. It covers 14,600 acres in Cumbum Valley, 45,000 acres in Periyar Main Canal (PMC)-double crop area, 96,534 acres in PMC - single crop area and 13,146 acres in Tirumangalam main canal (TMC).

After, the functioning of Periyar-Vaigai irrigation system nearly for six decades, it was observed that the entire water was not fully utilized and considerable surplus was still going as waste to the Arabian sea. Consequently, to make use of the Periyar water effectively for generation of power and irrigation, a dam was constructed in 1958 at the confluence of river Vaigai called Vaigai dam. The main canals and the branch canals[1] in PMC and TMC have been lined to prevent seapage loss under Periyar-Vaigai Modernization Scheme with the World Bank aid. The Fig.I shows the location of the system.

The problem of spatial distribution of water for the dominatingcrop in Periyar-Vaigai irrigation system viz. rice has been studied and reported in this paper. The study aimed to analyse the different practices of water distribution in terms of quantity and timing for the entire irrigation system and to find out how the quantity affected the productivity. The findings relate to the second crop of normal water year 1981-82.

Methodology:

The Periyar-Vaigai command area has been delineated into four regions based on the homogeneity in cropping pattern and water supply as follows :

i) Cumbum Valley
ii) PMC-Double crop area
iii) PMC-Single crop area
iv) TMC

For the selection of fields, a three stage random sampling procedure was adopted. Out of four regions three regions were

selected to represent head, middle and tail-end of the entire system. Accordingly Cumbum Valley, PMC - double crop and PMC-single crop areas were selected to represent head, middle and tail and respectively. A distributory[2] or minor[3] was selected in each region. The TMC area was not covered during the year under report. The details of the water course selected for the study in each region are furnished in Table I.

In the first stage, the selected distributory or minor was divided into three portions representing head, middle and tail based on the off-take from the minor or branch canal as the case may be. The details are presented in Table II.

At the second stage, one sluice in each of head, middle and tail reaches irrigating approximately 25 acres was selected. At the third stage, after identifying the peculiar sluice, the field channel was divided into two halves as head and tail end considering the total length of the channel and one field in each half was selected as explained in Table III. In all six fields were selected randomly in each region.

The data were collected on timings of irrigation, quantity of water supplied and the daily cultivation operations such as data of sowing, planting, harvesting, stress days and yield data for all the selected fields by the field investigators in each region. In selectingthe fields, care was taken to select the fields which were irrigated directly from the field channel and not through adjacent fields.

Results and discussion

The results of the study are presented and discussed below : First, a brief description of the system of water allocation is presented for understanding the inference fully.

The present riparian law provides that the oldest part of the command area should have priority in the water allocation over the newly developed area. The priorities are that the old

double crop area should receive irrigation for two crops and excess water is then supplied to single crop lands and after meeting these major demands, further surplus if any will be released for any area of future extension. The existing priority in distribution of the water in different regions are as follows :-

S.No.	Region	Period of water supply
1.	Cumbum Valley	Jan 1 to Feb 28
2.	PMC-Double crop area	- do -
3.	PMC-single crop area	Aug 15 to Feb 15
4.	TMC	Sep 1 to December 31

In normal periods, water will be released on June 1 for Cumbum Valley and PMC - double crop area. If the water is not sufficient to meet the demand of Cumbum Valley and PMC double crop area, then the data of release of water supply for both the regions will be postponed. Suppose, the water supply is just sufficient to stabilize the area under Cumbum Valley and not for PMC - double crop area, then the water is supplied only to Cumbum Valley.

However, the period of water supply mentioned above will be adhered only for normal years and during the scarcity periods water is supplied on different dates based on the priority and availability of storage water at the dam.

Distribution of water among farmers :

The methods of irrigation differ widely among different regions. In Veerapandi channel, there are 25 sluices irrigating two villages. For each village, one waterman (Neerani) has been appointed by the villagers to regulate water supply among the sluices. The watermen liaise with the lascar[4] of the Public Works Department who has official control in regulating water supply. By mutual understanding and contact, watermen of different villages in a water course share the supply of

water proportionately among their villages. The waterman in each village observes and regulates the supply of water from each sluice based on the need. The water supply for each field is again regulated by a water guide(Neerkatti) appointed by the farmers of each field channel. He is a full time worker and his job is to see that all the fields are irrigated in time. Especially at the time of scarcity period, he judiciously distributes the available water to all fields irrespective of their location. This type of management could be seen only here and is practised for more than seven decades in this village. This arrangement avoids group clashes between head enders and tail enders of the canal is sharing the water. The farmers in the canal ayacut never irrigate their fields or engage separate water guide for their fields individually. In other two channels, namely Tamarapatti and Navanipatti channels there is no such arrangement with a common waterman. Table IV details out the number of sluices and the distribution of water guides in head, middle and tail ends for Veerapandi channel.

Unlike the Veerapandi village, the distribution of water among sluices in Tamarapatti and Navanipatti channels is vested with section officer, in the Public Works Department, Government of Tamil Nadu. Based on the farmers demand he instructs the lascar to supply more or less water for a particular field channel. Once water is supplied to the field channel, the farmers distribute the same among themselves.

The sharing of water among the farmers in Tamarapatti and Navanipatti channels are different from Veerapandi channel. In these two villages each farmer would employ either permanent or special or family labourers exclusively for irrigating their fields. Some of the medium farmers and the big farmers used to employ special labour for irrigation along with their permanent labour if they face any difficulty in irrigating their farm. For that he is paid Rs.150/- or 150 kg of paddy

grains in Chittampatti village irrigated by Tamarapatti channel and Rs.100 or 80 kgs of paddy grains in Navanipatti village. The pattern of labour employed for irrigation in Tamarapatti and Navanipatti channels are presented in Table V.

Employing a common water guide or waterman for each channel as practiced in Veerapandi channel is not prevalent in Chittampatti and Navanipatti villages since the village leadership (Nattanmai) are not functioning properly. Even for cleaning or desilting the channel before the receipt of water, farmers are not co-operating. Generally, the tail enders used to clean only the field channel and the farmers expect the Government to clear the main and other channel. But in Veerapandi channel, all the farmers, both head and tail enders, join together and clean the main channel and the water guide used to maintain his channel neatly.

Distribution of paddy variety and time of sowing :

In Veerapandi channel the farmers would decide the variety to be cultivated before the commencement of crop season and uniformly cultivate this variety in the entire area of the channel. The sowing is taken up simultaneously irrespective of the location of the fields with a time allowance of three days. Hence this helps the waterman and water guide in allocating the water uniformly to all farms.

On the contrary, in Thamarapatti and Navanipatti areas, it was noticed that the farmers selected different varieties according to their choice. It caused more water loss in the form of transmission loss from head to tail reach. Consequently, harvesting of the crop also extended nearly 42 days in Navanipatti and 16 days in Tamarapatti channel areas. The details of variety, sowing and harvesting dates for different regions are given in Table VI.

It was observed that in Veerapandi the farmers adopted uniform data of sowing though the lands were double crop wet lands.

But in Tamarapatty channel, there was no consistency in time of sowing with reference to location of the fields. The sowing of second crop was largely influenced by the probable date of harvest of the first crop. In as much as different varieties are grown in first crop season and they come to maturity at different periods, date of sowing of nursery for the second crop also would fluctuate. It was observed in Tamarapatty channel ayacut that the first sowing and last sowing of second crop were done on 22-6-1981 and 28-10-1981 respectively thereby indicating the spread of sowing operation over 67 days.

In Navanipatti, the lands were single crop wet land and the farmers chose their own time for sowing depending on the choice of variety and other facilities available. The first and last dates of sowing in a particular sluice was observed to be 28-8-81 and 3-10-81 respectively. The water supply in the normal year did not affect the timing of sowing of paddy nursery.

Size of holding :

The size of operational holding and the number of fragments in farms under question have a definite bearing on the time of sowing in a particular channel.

Since the size of holding in Veerapandi village, was inavaiably small as compared to other regions, it is possible to stick on uniform time of sowing as well as harvesting. On the contrary in the case of Tamarapatti channel area not only the size of holding was high, the number of fragments were also more (in some cases more than 20 fragments) and this has resulted in the variation of time of sowing and harvesting. The details are presented in Table VII. However, the results are to be continuously considered in view of small size of the sample.

Water use :

The water use in different locations of the irrigation system was assessed by measuring the quantity of water used by the farmers both at the head and tail ends of the sluices, for head, middle and tail portion of the channel. In general, the farmers located at the head used more water than the farmers located at the tail ends. The level of water use at different locations is furnished in Table VIII. From the table it could be seen that on an average the farmers had used 297.4 cm and 295.0 cm in Veerapandi channel at the head and tail of the sluices respectively. As regards Navanipatti channel the level of the water use is invariably high as against other two regions.

Since Cumbum Valley enjoys the benefits of location at the head and end of the irrigation system, the Veerapandi farmers use more water than the farmers in Tamarapatti channel. The difference in water use between the head and tail ends is only marginal because of good distribution and management of the concerned waterman and water guide.

Further, both head and tail enders used more water as compared to the level of water used, i.e. 104 cm in the experiments conducted for IR 20 variety at Agricultural College and Research Institute, Madurai.

Regarding the water use in Tamarapatti and Navanipatti channel, the difference between near and far-off fields within a sluice indicated that by and large the fields located in first half used relatively more water. The yield variability between different regions are remarkable. Inavariably, the yield realised was higher in Cumbum region as compared to Tamarapatti and Navanipatti channels. Further, it could be also seen from Table VIII that the difference in yield between the farmers at the first half and second half sluice were only marginal. Since, Navanipatti is located at the other extreme the regional

differences in yield was maximum in this area as compared to Tamarapatti channel.

The yield variability is not due to water use alone and it is contributed by many other factors which are not the purview of this paper. However, it may be indicated that the soils in Veerapandi ayacut is relatively old and fertile, followed by Tamarapatti and Navanipatti in that order.

Conclusion :

From the foregoing discussions it could be inferred that equity is ensured in the distribution of water in Veerapandi channel where management of distribution has been vested with a common agency appointed by the village community. There was significant difference in the productivity of the crop in this region as compared to other regions.

The problem of equity is aggravated in Tamarapatty and Navanipatty channels due to several factors like lack of organized efforts to share and manage water distribution, lack of coordination in choosing the varieties of rice to be grown and deciding the time of sowing, and organizational pattern of land holdings, viz, too many fragments.

Differences in productivity within a given region is not significant.

Policy suggestion :

i) Irrigation management at distribution points by community effort as is done in Veerapandi is commended.

ii) Choice of variety of crop and time of sowing shall be decided through farmers committees to maintain uniformly in distribution and regulating water supply in the ayacut.

iii) Attempts to consolidate the holding should be made so that the fragments could be minimised to facilitate management at field level.

iv) Regulating the supply at head reach in accordance with actual field level requirement would help conserving water at the storage points itself. The differences in water use at farm level and experimental station need serious consideration.

* * *

Table I

DISTRIBUTION OF SELECTED WATER COURSES IN THE PERIYAR-VAIGAI IRRIGATION SYSTEM

S.No.	Region	Name of the water course	No.of villages bene-fitted	Area under irrigation (in ac.)	Total length of channel in km.
1.	Cumbum Valley	Veerapandi channel (Branch channel)	2	322.54	2.80
2.	Periyar-Main canal(PMC) Double crop area	Tamarapatti channel (Minor)	1	415.59	1.82
3.	Periyar-Main Canal (PMC)- Single crop area	Navanipatti channel (Distributory)	3	548.05	2.50

Table II

DISTRIBUTION OF SLUICES ACCORDING TO DISTANCE

.No.	Name of the channel	Distance from the off take in km	No.of sluices	Total ayacut (acres)	Ayacut of selected sluices (ac)	No.of farmers under the selected sluices	Average size per farmer (acres)
1	2	3	4	5	6	7	8
.	Veerapandi channel:						
	Head sluice	0.70	5	41.98	22.44 (53.45)	26	0.86
	Middle sluice	1.18	10	122.70	23.54 (19.19)	32	0.74
	Tail sluice	1.90	10	138.86	25.79 (18.57)	33	0.78
	Total	2.80	25	303.54	71.77 (23.64)	91	0.79
2.	Temarapatty channel:						
	Head sluice	0.07	3	38.50	10.04 (26.08)	7	1.43
	Middle sluice	0.70	2	115.36	25.08 (21.74)	15	1.67
	Tail sluice	1.31	4	261.73	63.31 (24.19)	14	4.52
	Total	1.82	9	415.59	98.43 (23.68)	36	2.73
3.	Navanipatti channel:						
	Head sluice	0.83	2	226.58	19.45 (8.58)	17	1.14
	Middle sluice	1.51	4	127.88	22.96 (17.95)	15	1.53
	Tail sluice	2.47	4	193.59	49.37 (25.50)	14	3.53
	Total		10	548.05	91.78 (16.75)	46	2.00

Note : Figures in paranthesis indicate the percentage to total ayacut.

Table III

LOCATION OF FIELDS IN THE SELECTED SLUICE

(in metre)

S.No.	Name of the channel	Haid		Middle		Tail	
		First half	Second half	First half	Second half	First half	Second half
1.	Veerapandi	3.00	13.50	2.40	16.20	3.06	24.30
2.	Tamarapatti	16.52	376.20	132.24	431.68	5.00	570.00
3.	Navanipatti	290.00	540.00	5.00	250.00	1.50	310.00

Table IV

DISTRIBUTION OF WATER GUIDES AND AVERAGE AREA FOR EACH GUIDE IN VEERAPANDI CHANNEL

S.No.	Particulars	Head	Middle	Tail	Total
1.	No.of sluices	5	10	10	25
2.	Area under irrigation (in acres)	41.98	122.70	138.86	303.54
3.	No.of water guide	5	13	16	34
4.	Average area per water-guide (in acres)	8.40	9.44	8.68	8.93

Table V

PATTERN OF LABOUR EMPLOYED FOR IRRIGATION IN TAMARAPATTY AND NAVANIPATTI CHANNELS

Particulars	Special Labour		Permanent Labour		Family Labour	
	First half	Second half	First half	Second half	First half	Second half
Tamarapatti:						
Head	-	-	-	-	1	1
Middle	1	-	-	1	-	-
Tail	1	1	-	-	-	-
Total	2	1	-	1	1	1
Navanipatti:						
Head	-	-	-	-	1	1
Middle	-	-	1	-	-	1
Tail	-	-	-	-	1	1
Total	-	-	1	-	2	3

Table VI

DISTRIBUTION OF PADDY VARIETY IN THE SELECTED FARMERS

	Variety		Date of sowing		Date of harvest	
	First half	Second half	First half	Second half	First half	Second half
1. Veerapandi:						
Head	IR.20	IR.20	27.10.71	27.10.81	17.3.82	20.3.82
Middle	IR.20	IR.20	28.10.81	28.10.81	20.3.82	21.3.82
Tail	IR.20	IR.20	28.10.81	28.10.81	19.3.82	25.3.82
2. Tamarapatti:						
Head	IR.20	IR.20	11.10.81	7.10.81	28.2.82	25.2.82
Middle	IR.20	IR.20	26.9.81	7.10.81	13.2.82	21.2.82
Tail	IR.20	Ponni	29.9.81	4.10.81	19.2.82	12.2.82
3. Navanipatti:						
Head	IR.20	Ponni	2.9.81	5.9.81	19.1.82	19.1.82
Middle	Ponni	Ponni	4.9.81	17.9.81	12.1.82	23.2.82
Tail	Ponni	IR.20	30.8.81	3.9.81	3.2.82	25.1.82

Table VII

DISTRIBUTION OF SIZE OF HOLDING IN THE SELECTED FARMERS

(Area in acre)

	Operational size		Holding No.of fragments		No. of wells	
	First Half	Second Half	First Half	Second Half	First Half	Second Half
1.Veerapandi:						
Head	2.30	1.60	1	1	-	-
Middle	1.50	2.70	1	2	-	-
Tail	1.28	0.70	1	1	-	-
Average	1.68	1.67	1	1.3	-	-
2.Tamarapatty:						
Head	3.00	5.89	7	19	-	-
Middle	13.00	11.50	40	17	1	1
Tail	14.75	15.00	19	24	1	1
Average	10.25	10.80	22	20	0.67	0.67
3.Navanipatti:						
Head	4.50	4.50	11	15	-	-
Middle	11.50	3.20	45	7	1	1
Tail	4.40	5.62	10	16	1	1
Average	6.80	4.44	22	12.70	0.67	0.67

Table VIII

CONSUMPTION OF WATER BETWEEN HEAD AND TAIL ENDERS

	Total water consumption in cms		Stress days		Yield/acre in kgs	
	First half	Second half	First half	Second half	First half	Second half
1. Veerapandi						
Head	271.0	300.0	5	6	2330.0	2500.0
Middle	316.0	277.0	5	5	2175.0	2300.0
Tail	297.0	309.0	5	4	2030.0	2100.0
Average	294.7	295.3	5	5	2178.7	2300.9
2. Tamarapatti						
Head	311.0	293.0	11	12	1470.0	2080.0
Middle	268.0	147.0	12	9	2067.0	2600.0
Tail	221.0	230.0	10	8	1360.0	1480.0
Average	266.7	223.3	11	9.7	1633.0	2053.3
3. Navanipatti						
Head	447.0	243.0	5	7	1017.0	1462.0
Middle	227.0	341.0	9	8	1698.0	1573.0
Tail	381.0	313.0	6	9	1394.0	1342.0
Average	368.3	299.0	7	8	1369.7	1459.0

Notes

[1]takes-off from the main canal

[2]takes-off from the branch canal

[3]takes-off from the distributory

[4]Lascar is a basic servant in the P.W.D who is vested with the responsibility of opening the sluices, control the distribution of water and take water reading at head sluice and other sluices under the instruction of the Section Officer (Engineer) in-charge of the channel.

8

PRODUCTIVITY AND EQUITY IN MINOR IRRIGATION TANKS

A. Sundar & P.S. Rao*

Introduction

The monsoons in India are confined, in most parts of the country, to a period of about four months and the quantity and time of occurrence of rainfall seldom match the requirements of crops, especially the high yielding varieties. Water being a vital input for sustenance of crops, recourse, hence, has to be taken to supplying water through man-made structures. Thus irrigation has developed over centuries in an attempt to overcome the limitations of inadequacy and untimeliness of rainfall. Minor irrigation tanks constitute an important source of irrigation in the Southern States of Karnataka, Tamil Nadu and Andhra Pradesh.

Increased agricultural production, equity and maintenance of environmental stability are taken as the objectives of irrigation development. Agricultural production sustained over a long time horizon will cover environmental stability to a large extent. Thus sustained agricultural production and equity can be considered as the objectives of irrigation development.

Excluding some groundwater developments, most of the irrigation works are in the public sector. The investments are made by the government and the concerned government department maintains and operates the system upto the outlets. The farmers have the responsibility below the outlets.

The system supplies an input utilised by a large number of individual farmers taking their own decisions on types of crops to be grown, cultural practices, and many other crop-related decisions

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influenced by their individual preferences, resource endowments, accessibility to information, risk taking abilities and other factors.

Thus, while discussing irrigation management, it is necessary to consider the two viewpoints, that of the government and that of the farmer. The government looks at it as a public investment basically intended to increase agricultural production. The other viewpoint is that of the farmer to whom water is an input, an essential input that will enable the use of other inputs such as better seeds, fertilizers and pesticides.

There is no such entity, however, as a typical farmer. The farmers in the command area are many and are differentiated by the extent of land-holding, characteristics of the soils of their holdings, family size, educational attainments, other resource endowments, access to knowledge and information, proximity and relationship to sources of political power, place in social structure and many such factors. Nevertheless, it can be stated that what is typical is that all of them are engaged in a venture that demands decision-making in the face of uncertainty. The uncertainties pertain to weather, prices, availability and quality of inputs such as seeds and fertilizer, adequacy and timeliness of irrigation and incidence of pest attacks. Their objective is to maximise sustained income and reduce its variability subject to constraints imposed by status and social standing (consuming home-grown food), maintaining the proprietorship over land and such other considerations.

Therefore, any objective that the government (society) desires to achieve can be attained only if it is in consonance with what each individual farmer wants and its collective effect.

In this connection, the spatial and hydraulic aspects of irrigation networks have to be given due weightage. Location of a farm with respect to the distribution system immediately places certain advantages or disadvantages. The dynamic actions of flow of water

again confer differential advantages and disadvantages on upstream and downstream farmers. Downstream farmers have to counteract more the tendency of water to destroy its physical confines unless constantly attended to. This attention may not be possible by individual farmers and would need collective action since the downstream farmer faces the cumulative effect on the physical system upstream of him.

Productivity

Agricultural production is a function of innumerable factors among which are soil characteristics, weather conditions, inputs like seed, fertilizer and water, pest control, cultural practices, and supervision and management. Water is a key input which also enables the use of other inputs.

The total production in terms of the usable product, say, grain or fibre, will depend on all the relevant factors in a very complex fashion. Because of interactions among the innumerable factors, some unknown and some known, production is a variable that has some inherent randomness.

The contribution to productivity that a particular factor or input, say, water, makes is of particular interest when one is faced with the problem of its utilisation, especially if it is scarce. In this context, it is also of relevance to know whether this factor is controllable and if so to what degree; and if it is controlled, the extent possible, and how it contributes to production in the presence and absence of controls over other inputs. Further, does the variability in production remain or not and to what extent it remains when controls are exercised over this particular input?

To the farmer, production in terms of say, grain, will be of interest only if it is all for consumption or utilization in another process as an input which cannot be met otherwise. What is more generally applicable is the income that this production

generates when the surplus, after the consumption and other uses are provided for, is marketed. Thus production and productivity in financial terms are of importance. These depend upon prevailing prices, and their characteristics (whether administered or not), market access, ability to keep stocks, debt-service requirements, etc. Thus agricultural production and productivity depend upon a number of factors among which water is one. Production and productivity of water alone, thus, is a function of all the other variables. To individual farmers, these other variables are specific and their quantum and quality vary. To the public agency, a collection of these individual farmer situations constitutes the basket that could be utilised for production and productivity due to water.

In this connection the first task faced by the agency is the assessment of the quantum of water available in the tank. Spatial and temporal variability of rainfall, the source of water, are well known. Stream-flow being a random variable, one can only assess it in a probabilistic sense. Added to this are the uncertainties introduced by lack of hydrometeorological data and hence use of empirical relationships developed for use with inadequate data. Yields are still assessed on the basis of Strange's and Binnie's approaches developed many decades ago on the basis of limited observations.

On the basis of this yield assessment and crop-water needs based on a proposed cropping pattern arrived at in consultation with agricultural experts, the command area is delineated and distribution system designed.

Obviously, in a command with a variety of crops being grown, water supply cannot match the requirements of each and every one of them. Further from the point of production alone, provided the soil and weather permit different crops, the crops raised would be functions of prices and water consumption per unit output.

Water rates are assessed on a per hectare basis and on the crops

grown. To individual farmers, therefore, water from a public system has zero marginal cost and hence the level of its usage is at or higher than the point where the production function attains its highest value. The incremental productivity of water at this level is, zero, and tends towards negative levels if water application is increased further, although, generally, the response curve is rather flat in the neighbourhood of the highest point. This leads to head-end farmers using more water than necessary.

To the agency in charge of the system, productivity of water is of concern. Therefore, its aim is to spatially and temporarily so distribute water, subject to soil conditions, that incremental or marginal productivities of water applied at different locations are equal and if possible at the highest level of production. The equality is from consideration of water released at the head-works and therefore water applied at a farther point should have higher productivity than at a nearest point to compensate for losses in transit. Similar considerations require that water applied at a season when storage is drawn down should have a higher productivity compared to the season where storage is built up to compensate for evaporation losses.

Thus for achieving higher productivity of water impounded, from the point of view of the public agency, a compact command area that minimises transit losses is to be preferred, so also crops that produce higher value per unit consumption of water. Also, since water is the controllable but scarce resource, irrigation application has to be at a level lower than what is required for maximum production per unit land.

Land is generally a fixed and scarce resource for the farmer and therefore from his productivity considerations water has to be applied to attain maximum production from land or at a level where marginal productivity of water is zero. More so, when he pays water rate on a per acre basis and not on a volumetric basis.

Thus the question of productivity from the two view points raises completely conflicting requirements; in one, water is the fixed (and scarce) resource, in the other, land. Also reaching the production and productivity considerations of the agency will require individual farmers moving away from their requirements. This may need imposition of suitable constraints by technical, economic, institutional and organisational means. Whether such constraints can be devised and imposed upon is the whole crux of irrigation management.

Equity

Among the objectives pursued by the society, one is equity, which has impact on the distribution of benefits and costs to various segments of the society. Absolute equality and uniformity are not what are desired or intended since this is impossible given the differences in the intrinsic qualities among individuals and their preferences. However, equity is meant in the sense of fairness in the distribution of opportunities, goods, services, knowledge and information that enable the development of the individual and the family which in the aggregate form the society. This implies recourse to principles of justice to correct or supplement law, i.e. valid in equity as opposed to law. Equity in the broad sense impinges on all sectors of activity : irrigation, education, health and others.

Equity is a beautiful concept in the abstract but very difficult to operationalise. Governments do undertake measures leading to greater equity. For example, income tax is levied on a graded scale on incomes higher than a stipulated base level. The same health services are provided in a hospital but the charges levied increase with the income of the individual. Similar is the case in education. Whether such measures devised to attain more of equity are adequate is a matter of perception and subjective judgement.

Considerations of quity are important in irrigation at least at two levels. One is the choice of the projects and the other is the distribution of water among farmers. Even while deciding on which of the innumerable irrigation projects (tanks) will be taken up for implementation and in what order, equity considerations have to be resolved. In public systems the political process is to do this. The very creation of irrigation systems can once again bring in equity questions since persons are displaced to create the storage. Leaving aside such questions of equity in the larger context, what is being considered is equity only in the context of a given irrigation system (tank) since we can exert some control over distribution of water at this level.

In any tank command the holdings of land are highly unequal. A small percentage of large farmers holds a large extent of land, while the bulk of the farmers has small holdings. It is not the function of an irrigation system to correct this. There are other instruments like land reforms devised by the society to address this question.

Given this situation, equity implies that the input, water, supplied by the public system should be distributed as fairly as possible all along the system. Since this input enables the use of other inputs, it should be available at least to the level, if such a threshold exists, that will permit the use of other inputs, so that no one is denied the chance of using improved agricultural practices. However, it should be noted that providing water alone does not enable this, since requirements of credit, labour, etc., have also to be met. None-the-same, at least one constraint is relaxed when water is provided.

Since soil conditions vary and crops planned could also be different, providing water to a level that enables use of other inputs is not easy. If only a single type of crop is grown all over the command the problem is relatively simpler. However, with a variety of crops grown, an operational form of equity is needed. Thus equity in distribution of water has often been taken as equality in water

available per unit of land. Rostering of supplies is intended to achieve this. A measure of equity achieved, can perhaps be the comparison of crop pattern at different locations of the system and their yields (correcting for constraints on use of other inputs and allowing for differences in soil conditions and whether this constraint is water).

Productivity and Equity in Minor Irrigation Tanks in Karnataka

In connection with a study on "Farmers' Participation in Tank Irrigation Management", 1, 2, 3 extensive survey was done of farmer perceptions and attitudes in a few selected tanks.

Among the tanks studied were Hanchinal in Bijapur District (355 ha.), Doddalahalli in Bangalore district (300 ha.) and Ambligola in Shimoga district (2000 ha.). Hanchinal is a relatively new and a well maintained tank, whereas Ambligola and Doddalahalli are older structures and their maintenance is less than adequate.

In Hanchinal 50 out of 108 farmers were interviewed, while at Amgligola and Doddalahalli it was 106 out of 256 and 120 out of 255, respectively.

Regarding productivity no firm data on yield and such measurable indicators were available. However, indicators such as cropping pattern and cost of cultivation were collected. These could throw some light on productivity and its variations in the system, in the absence of other data.

In order to assess whether location of the farm influences the choice of crop pattern, the farmers were asked whether there were any differences in the choice of crops between head and tail-end farmers and the reasons for the differences, if they existed. Similarly, they were asked to comment upon the differences in cost of cultivation.

In Hanchinal and Doddalahalli, the farmers do not perceive any differences in the cropping pattern, at various locations in the system. Also, in Ambligola, the majority (78%) does not perceive any difference. However, those who do, attribute it to water and economic reasons.

Similarly, regarding the cost of cultivation, the majority of farmers, 78% in Hanchinal and 84% in Ambligola, do not think that location has any effect on cost of cultivation. A few who perceive differences in cost of cultivation, attribute it to water.

Regarding equity, the farmers were asked whether they got adequate supply of water whenever they needed and whether they got enough water for each crop. They were also asked about their perception of equity in water distribution-equity among outlets and equity below outlet.

Hanchinal farmers perceive that water supply is adequate for every crop and there is equity, by and large, in distribution. However, some tail-end farmers feel that there is not enough equity in distribution of water among the outlets.

In Ambligola and Doddalahalli, availability of water is a function of the location of the farm. Tail-enders receive relatively inadequate water. Also a significant percentage of tail-end farmers perceive inequity in distribution (Tables 1 to 7).

One of the main differences between Hanchinal on one hand and Ambligola and Doddalahalli on the other, is the quality of the physical system.

Modernisation of Tanks for Better Equity and Productivity

Gundamagere tank situated near Doddaballapur in Bangalore district is an example of modernisation contributing to equity. The tank, as per the original design, was intended to irrigate 200 ha. (500 acres) of wet (mainly paddy) crops. The PWD during the later

part of the last decade, increased the capacity of the tank from 2.86 m.cu.m. (72.72 m.c.ft.) to 2.8 m.cu.m (98.70 m.c.ft.) by raising the waste weir by 90 cm. (3 feet) and converting it to a high co-efficient weir as well as raising the top level of the embankment. This resulted in the increase of irrigated area to 334 ha. (835 acres). They also had meetings with the farmers to persuade them to go in for irrigated dry crops (Ragi, Maize, Jowar and Groundnut). It is reported that the farmers are growing mainly irrigated dry crops from 1977 onwards.

A further improvement that has been largely carried out (work is still in progress) is the lining of the distribution system and provision of suitable outlets and control structures. This has enabled the increase of the irrigated area to 400 ha. (1000 acres).

Since the tank lies in an area of low rainfall (around 500 mm), the uncertainty of water availability is fairly high as indicated by the tank contents in the previous few years (Table 8). Despite this hydrologic condition, the irrigation achieved has been considerable (Table 9).

Since modernisation, there has been a drastic change in the crop pattern (Table 10).

Interviews with farmers in the command have shown that, after modernisation, distribution of water has become more equitable. An indicator of this is that crop pattern is more or less the same at all reaches of the system.

There are also claims that, because of better control on water after modernisation, there has been some increase in yields. Ragi yield is said to have increased from 20 quintals to 30 quintals per hectare. Similarly Jowar is said to be yielding 80 quintals as against 63 quintals.

Groundnut cultivation has picked up considerably. For example,

in 1974-75 Rabi, groundnut was grown in 28 ha. (70 acres) while in 1977-78 Rabi, it was 192 ha. (480 acres) and in 1979-80, 304 ha. (760 acres). Yield of groundnut has changed as follows :

Year	Yield (Quintal/Hectare)		
	Maximum	Minimum	Average
1977-78	30	15	20
1979-80	47	25	28

While the number of farmers applying chemical fertilizers was almost insignificant in 1975-76, it was 183 (45% of the farmers) in 1977-78. Average fertilizer application, NPK in Kg./Ha., increased from 11:71:28 in 1977-78 to 21:75:33 in 1978-79.

In this context it is pertinent to point out that agricultural extension has been non-existent since the agricultural extension worker has not been there since the past 3 years.

According to one farmer any difference in yields is mainly attributable to the capacity to finance rather than location along the system. Even the farmers, who say there has been no change in yield after modernisation, state that there is better control over water.

Concluding Remarks

Data on productivity in minor irrigation tanks are hard to come by. However, some insight can be had from indicators such as cost of cultivation and cropping pattern.

In general there is inequity in distribution of water. However a good physical system seems to be a main requirement for attaining equitable distribution.

Modernisation of minor irrigation tanks does contribute to increased productivity and equity. Unless beneficiaries are also well organised, the full benefits from modernisation may not be realised. In the example of Gundamagere tank also, farmers did complain about tail-end problems, although admitting that modernisation has improved controllability. Officials complained about unauthorised irrigation and welcomed the idea of organising farmers and involving them in maintenance and operation.

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Table 1 : Differences in Choices of Crops and Varieties Between Head and Tail-End Farmers

Tank	HANCHINAL				AMBLIGOLA			
	Proximity	Yes	No	No Idea	Proximity	Yes	No	No Idea
		(in percentage)				(in percentage)		
1.	HH	-	66.67	33.33	HH	12.50	75.00	12.50
2.	HM	-	71.43	28.57	HM	30.00	70.00	-
3.	HT	-	100.00	-	HT	20.00	80.00	-
4.	MH	-	60.00	40.00	MH	13.64	81.82	4.54
5.	MM	-	75.00	25.00	MM	-	100.00	-
6.	MT	-	50.00	50.00	MT	-	93.33	6.67
7.	TH	-	100.00	-	TH	10.00	80.00	10.00
8.	TM	20.00	40.00	40.00	TM	22.22	66.67	11.11
9.	TT	-	38.46	61.54	TT	33.33	44.45	22.22
Total		2.00	62.00	36.00		14.42	78.85	6.73

Note : In HH, HM, etc., the first letter refers to location on the main canal and the second letter to location along the field channel.

H, M, T refers to Head, Middle and Tail-ends.

Table 2 : Reasons for Differences

Tank : AMBLIGOLA

Sl. No.	Proximity	Water and Economic Studies	No Differences
		(in percentage)	
1.	HH	12.50	87.50
2.	HM	16.67	83.37
3.	HT	20.00	80.00
4.	MH	18.18	81.82
5.	MM	-	100.00
6.	MT	-	100.00
7.	TH	-	100.00
8.	TM	22.22	77.78
9.	TT	33.33	66.67
Total		13.21	86.79

Table 3 : Differences in Cost of Cultivation Between Head and Tail-End Farmers

Tank	HANCHINAL				AMBLIGOLA			
	Proximity	No Difference	Yes	No Idea	Proximity	No Difference	Yes	No Idea
		(in percentage)				(in percentage)		
1.	HH	83.33	-	16.67	HH	75.00	12.50	12.50
2.	HM	85.71	-	14.29	HM	75.00	25.00	-
3.	HT	80.00	-	20.00	HT	80.00	20.00	-
4.	MH	80.00	-	20.00	MH	86.36	9.09	4.55
5.	MM	50.00	-	50.00	MM	100.00	-	-
6.	MT	100.00	-	-	MT	93.33	-	6.67
7.	TH	66.67	-	33.33	TH	100.00	-	-
8.	TM	80.00	-	20.00	TM	77.78	11.11	11.11
9.	TT	76.92	-	23.08	TT	66.67	33.33	-
Total		78.00	-	22.00		84.91	11.32	3.77

Table 4 : Reasons for Difference

Tank : AMBLIGOLA

	Proximity	Economic Status	Water	No Difference
			(in percentage)	
1.	HH	-	25.00	75.00
2.	HM	8.33	16.67	75.00
3.	HT	10.00	10.00	80.00
4.	MH	-	9.09	90.91
5.	MM	-	-	100.00
6.	MT	-	-	100.00
7.	TH	-	-	100.00
8.	TM	-	11.11	88.89
9.	TT	-	33.33	66.67
Total		1.89	10.37	87.74

Table 5 : Availability of Water

Tank	HANCHINAL			AMBLIGOLA			DODDALAHALLI		
	Proximity	Yes, when tank is full	No	Proximity	Yes, when tank is full	No	Proximity	Yes, when tank is full	No
		(in percentage)			(in percentage)			(in percentage)	
1.	HH	100	-	HH	100.00	-	HH	100.00	-
2.	HM	100	-	HM	91.67	8.33	HM	83.33	16.67
3.	HT	100	-	HT	50.00	50.00	HT	75.00	25.00
4.	MH	100	-	MH	90.91	9.09	MH	92.31	7.69
5.	MM	100	-	MM	81.82	18.18	MM	64.29	35.71
6.	MT	100	-	MT	80.00	20.00	MT	53.85	46.15
7.	TH	100	-	TH	100.00	-	TH	61.54	38.46
8.	TM	100	-	TM	66.67	33.33	TM	53.85	46.15
9.	TT	100	-	TT	33.33	66.67	TT	14.29	85.71
Total		100	-		79.25	20.75		66.67	33.33

Table 6 : Availability of Adequate Water for Each Crop

Tank	HANCHINAL				AMBLIGOLA				DODDALAHALLI			
	Proximity	Kharif/ when tank is full	No Season	Yes	Proximity	Kharif/ when tank is full	No Season	Yes	Proximity	Kharif/ when tank is full	No Season	Yes
1.	HH	100.00	-	-	HH	87.50	12.50	-	HH	68.75	25.00	6.25
2.	HM	100.00	-	-	HM	75.00	25.00	-	HM	25.00	58.33	16.67
3.	HT	100.00	-	-	HT	30.00	50.00	20.00	HT	41.67	58.33	-
4.	MH	100.00	-	-	MH	77.27	9.09	13.64	MH	46.15	46.15	7.70
5.	MM	100.00	-	-	MM	81.82	18.18	-	MM	35.72	57.14	7.14
6.	MT	100.00	-	-	MT	80.00	20.00	-	MT	15.38	84.62	-
7.	TH	100.00	-	-	TH	100.00	-	-	TH	38.46	61.54	-
8.	TM	100.00	-	-	TM	66.67	33.33	-	TM	53.85	46.15	-
9.	TT	100.00	-	-	TT	33.33	66.67	-	TT	28.57	64.29	7.14
Total		100.00	-	-		71.70	23.58	4.72		40.00	55.00	5.00

Table 7 : Equity in Water Distribution

Tank		HANCHINAL				AMBLIGOLA					DODALLAHALLI				
	Proximity	Complete Equity	No Equity at all	Equity below outlets	No Idea	Proximity	Complete Equity	No Equity at all	Equity below outlets	No Idea	Proximity	Complete Equity	No Equity at all	Equity below outlets	No Idea
1.	HH	83.33	-	16.67	-	HH	62.50	25.00	12.00	0	HH	62.50	37.50	-	-
2.	HM	85.71	-	14.29	-	HM	58.33	25.00	16.67	0	HM	75.00	25.00	-	-
3.	HT	100.00	-	-	-	HT	50.00	30.00	10.00	10.00	HT	58.33	41.67	-	-
4.	MH	100.00	-	-	-	MH	68.18	22.73	9.09	0	MH	61.54	38.46	-	-
5.	MM	100.00	-	-	-	MM	81.82	18.18	0	0	MM	50.00	50.00	-	-
6.	MT	50.00	-	50.00	-	MT	46.67	53.33	0	0	MT	38.46	61.54	-	-
7.	TH	66.67	-	33.33	-	TH	10.00	10.00	80.00	0	TH	53.85	46.15	-	-
8.	TM	60.00	-	40.00	-	TM	11.11	66.67	11.11	11.00	TM	23.08	76.92	-	-
9.	TT	69.24	15.38	-	15.38	TT	0	66.67	33.33	0	TT	14.29	85.71	-	-
Total		80.00	4.00	12.00	4.00		47.17	33.96	16.98	1.89		48.33	51.67	-	-

Table 8 : Storage in Gundamagere Tank

Date	Tank Contents
01-1-1979	No water
15-7-1979	(1.25 m.cu.m)
01-12-1979	Full*
01-6-1980	No water
01-12-1980	No water
01-6-1981	No water
01-12-1981	Full*
01-6-1981	(0.85 m.cu.m)

* 2.8 m.cu.m

Table 9 : Area Irrigated in Gundamagere Ayacut

Year	Area Irrigated (Hectares)	
	Kharif	Rabi
1974-75	226.8	214.8
1975-76	252.4	250.8
1976-77	252.4	246.8
1977-78	240.4	282.8
1978-79	376.0	260.0
1979-80	384.0	354.0
1980-81	400.0	-
1981-82	400.0	400.0

Table 10 : Cropping Patterns in 1974-75 and 1979-80 in Gundamagere Ayacut

Crops Grown	1974-75		1979-80	
	Kharif	Rabi	Kharif	Rabi
	(Hectares)		(Hectares)	
Groundnut	38	28	112	304
Ragi	25.6	24	98	8
Jowar	24.8	28	120	2
Mulberry	20	20	32	24
Tomato	4	14	4	4
Tobacco	-	16	-	-
Sugarcane	34.4	32.4	-	-
Paddy	80	52.4	14	8
Total	226.8	214.8	384	354

9

PERFORMANCE APPRAISAL OF TANK IRRIGATION SYSTEM - A MICRO LEVEL STUDY

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Introduction

Good management of water has always been recognized as an important component of successful irrigation all over the world. Lack of adequate water control on the other hand, has been a major constraint to crop production in many countries of Asia. Impressive evidence has accumulated over the past few years to show that a major cause of poor performance of irrigation schemes in many parts of the developing world has been deficient management, particularly in the operation of canal systems, which has resulted in marked inequalities in the pattern of water distribution between head reach and tail reach farmers and large and small farmers. In an aggregate examination of constraints, by Herdt and Wickham (1978), lack of water control was identified as accounting for upto 40 per cent of the difference between the apparent potential and actual yields in the Philippines (1).

Research studies made in Taiwan indicated (2) that rotational irrigation could achieve water savings of about 20 to 30 per cent without any reduction in rice yield. This method was also found favourable to plant growth and effective in saving fertilizer and labour and in the elimination of disputes over water. Rotational irrigation in Taiwan is also credited with significant extension of irrigated areas and in some cases, with higher grain yields. Another study made in the Philippines showed the severe inequity in water allocation and distribution that existed in a small gravity irrigation system although the total water availability in the system as a whole was adequate. The reasons for this inequity are basically misuse of water in

reaches closer to the source due to lack of adequate control and delivery schedules in the system by the management. It was estimated that equity could be ensured with such measures as controlling discharges from the existing turnouts, reducing the number of turnouts in the main canal and implementing a well-planned lay out of farm ditches to replace the existing but haphazardly constructed farm ditches; and that these improved facilities would be helpful in implementing scheduled water allocation to the different sections of the service area according to their felt needs. These measures would improve not only the water use efficiency in all sectors of the system but also permit expansion of the project's service area by utilising the resulting water savings to meet the irrigation requirements of additional areas. There is thus accumulating evidence that improved management can achieve both production and equity objectives on existing systems.

Background to the Padianallur Tank Irrigation Study

Water used in an irrigated farm is the result of a series of operations carried out at different points in an irrigation system. Generally the smaller the system, the less complex it should be to operate it in order to ensure equity. Irrigation tanks and small reservoirs have the advantage of the command areas being compact and located directly below them to facilitate better control and management of water, as compared to the major river valley system with their numerous structures in their head works, canals and distributories and large extent of command area. But an existing irrigation system irrespective of its size, has certain traditions and water rights built up over the years, which will be difficult to change even for providing equity of irrigation water. These traditions and rights are presumably influenced by the farmers' past experience with water availability and water sharing and the nature of control then existing for water allocation. While the conveyance, distribution and delivery facilities can be designed and constructed effectively to ensure equity and productivity, conflicts amongst the farmers

in the management of water will be the major problem to be overcome for the efficient operation of the physical facilities and the improvements made. These problems become particularly aggravated when the demand for water from all the farmers benefited by an irrigation source is simultaneous or when the demand exceeds the available supply.

Objectives of the Study

An irrigation system comprises of not only the physical and hydrological features but it also incorporates other related and vitally significant factors of economic, social, legal, environmental and ecological importance. Management of water in the land is undertaken by man within a prevailing physical, social, economic and social framework. It is therefore more than a technical function and calls for skilled water users and appropriate services and structures, together with adequate organisational or institutional support.

It is to develop such relevant techniques and methodologies based on the concepts detailed above, that a tank irrigation system has been taken up for study, in order to :

1. assess the present status of water development, utilization and management;
2. determine how the efficiency can be improved;
3. develop technology and management tools to achieve more efficient utilization of the available water;
4. implement the improvements designed;
5. monitor the impact of the improvements
6. evaluate the results in terms of equity and productivity; and
7. prepare guidelines for application of the useful results to the other tank irrigation systems.

The tank modernisation study is being undertaken by the Centre for Water Resources, College of Engineering, Anna University, Madras with financial support from the Ford Foundation, New Delhi. The public Works Department (Irrigation Wing), Government of Tamil Nadu, The Agricultural Engineering Department, Government

of Tamil Nadu and The Agricultural Economics Research Centre, University of Madras have been collaborating with the study.

Details of the Studies and Investigations

The studies were commenced during July 1981 in an irrigation tank in Padianallur village, Chengalpattu district, situated at about 21 kilometers north of Madras on the Madras-Calcutta National Highway. This is a non-system tank, receiving its water supply from rainfall from its own watershed and without any other supplementary source. The water in the tank is available for a period of 4½ to 5 months in a year from mid-October to mid-March.

Phase 1 of the investigation involved :

i. engineering survey of the watershed,

ii. computation of the area and water yield,

iii. collection of particulars of supply channels,

iv. detailed topographical survey of the tank bed,

v. computation of storage capacity of the tank for different depths and water-spread areas,

vi. taking levels and plotting the longitudinal and cross-sections of the tank bud,

vii. collection of specifications of the surplus weir and irrigation sluices,

viii. spot levels of the command area, longitudinal and cross-sections of all the main irrigation channels and the spot levels of adjoining fields, and

ix. preparation of maps or drawings.

Phase 2 of the investigation involved :

i. installation of the depth and flow measuring devices such as depth gauges in the tank bed and V notches in the main irrigation channels,

ii. establishment of bench-marks in selected wells in each of the three reaches to measure the water table,

iii. drum culture studies to record the deep percolation loss and evapotranspiration of the crops raised,

iv. installation of Parshall flumes to measure the seepage loss in selected sections of the main channels, and

v. in connection with the climatic analysis and crop transpiration study a meteorological field station was also installed at the tank site during February 1982.

The following weather data are observed at daily intervals :

i. Maximum and minimum temperature
ii. Dry and wet bulb air temperature (screened)
iii. Rainfall
iv. Open par evaporation to estimate tank evaporation poss.

Salient Features of Padianallur Tank

The engineering investigations and measurements made so far show the salient features of the tank as follows :

Particulars	Watershed		Waterspread	Command area
	Free	Intercepted		
Area	3.75sq.km.	3.10 sq.km.	97.28 ha.	252 ha.
Slope	1.5%	3%	0.5%	0.05%
Soils	Red loam	Red loam	Clay loam	Clay loam
Fertility status or condition	Moderately eroded	-	-	Low in organic matter content. Poor in available nitrogen and available potash and well supplied with phosphorous Free from salinity and alkalinity
Vegetation	Agri. crops 90% Barren 10%	Agri. crops 15% Eucalyptus tree plantation 20% Barren 65%	Weeds like nut grass (Cyperus spp.) " 40% Agri. crops 30% Barren 30%	

Irrigation water : good and suitable for irrigation. Storage capacity at full supply level : 0.721 m.cu.m. per filling. Number of fillings in a year (estimated) : two

Condition of the supply channels	:	Silted up and covered with weeds, resulting in reduced carrying capacity. The water supply from the intercepted watershed is negligible, as a syphon through which the run-off water is to flow into the tank is choked up with debris, silt and boulders.
Number of sluices	:	4

	Sluice No. 1	2	3	4
Command area (ha.)	78	132	34	8

Water control : Plug and rod type (sliding wooden shutters)

		Length (M)	F.S.L. (M)	M.W.L. (M)	T.B.L. (M)
Tank bund	:	1945	99.15	99.60	100.50

Surplus weir : 38.1 M long broad crested masonry weir with apron and revetment.

Present Status

While there is a negligible reduction of 0.43 per cent in the water spread area, from 97.70 ha. to 97.28 ha., due to silt accretion in the reservoir, the corresponding reduction in the storage capacity has been 11.75 per cent from 0.817 m.cu.m. to 0.721 m.cu.m. This silt accretion is caused by soil erosion from the watershed and cultivation of annual crops in the agricultural lands situated in the foreshore of the tank.

The tank bund which is designed trapezoidal in cross-section - 2 m. wide at top and 1½ : 1 front slope and 2 : 1 rear slope, is found cut down on the rear side by encroachers, resulting in some loss of tank water through seepage. The shape of the bund is also obliterated by cattle tresspass and erosion and it needs strengthening as well as provision of stone pitching on the water side.

As a measure of improving the communication and transport system between the farthest village and the marketing town nearby, the tank bund needs widening and improvement to serve as cart track as well.

While the surplusing arrangements are adequate to safely dispose off the anticipated peak flood discharge of 852 cusecs, the irrigation sluices are leaky and need repairs and improvements for better control and regulation of water according to the requirements. An additional sluice also needs to be constructed, in order to facilitate irrigation of fields situated at higher elevations and hence uncommandable at present by any of the existing sluices.

The main irrigation channels which convey irrigation water from the sluices are silted up, choked with weeds and are meandering, resulting in a sluggish flow of water. They have to be cleaned, the meanders are to be eased or straightened, the cross-sections are to be sectioned to hydraulically efficient shape and size and lined too, in order to increase their discharge capacity and thus convey the tank water to the farthest end of the command area with the least seepage loss. From each of these main channels some branch and field channels carry water to the rice fields.

Although the registered command area of the tank is 252 ha., the area actually cultivated by the farmers had been ranging from 164 to 240 ha., during the past several years, mainly due to inadequate storage of tank water.

Ground Water

The command area which is spread over three revenue villages has been divided into three reaches - the head, middle and tail end - based on the location of the fields - in order to examine whether there is any difference in the quantity of water received in these reaches and if so how best the supply can be made equitable. The farthest end of the command area is about 3000 meters away from the tank water spread. The water table during the pre-monsoon period in these reaches is 4.50, 5.00 and 5.5 meters respectively below the ground level, whereas it goes up to 0.35, 0.54 and 1.40 meters below ground level during the post-monsoon period when the tank gets filled up. There are 22 open and 16

shallow tube-wells sunk in the command area and energised with electric or diesel pump sets or motors and used for irrigation when the tank water is not available. These wells which get their recharge from the tank and by the percolation of the irrigation water applied to the lands, command an area of 95 ha. and the conjunctive use of surface and ground water being practised here has been helpful to increase crop production.

Water Regulation and Control

The water regulation is vested with a water guide employed by the farmers of the command area who pay him in kind. The water guide opens and closes the sluices and regulates water to each block of land-holdings on the basis of demand and mutual agreement amongst the land owners under the command of each sluice. In this arrangement, equitable water distribution is often subordinated to the influence of vested interests and often it is the tail-enders who are deprived of adequate water supply, particularly as the level of the tank water recedes. While the fields situated adjacent to the main channels get water directly through the openings made in their banks by heading up water when necessary, the other fields get their supply by field to field irrigation which is wasteful. In one sluice commanding a block of 27 ha. in one village and another block of 104 ha. in two other revenue villages further away (totally 131 ha.), turn system of water supply is resorted to on alternate days, resulting in inequitable distribution.

Land Drainage

Drainage water from the irrigated fields flow down the same channels which carry the irrigation water to the fields down below. There is no separate drainage system for the area. Provision of a network of drainage ditches and increased carrying capacity of the irrigation channels are to be made to improve land drainage during the monsoons when the fields get inundated.

Agricultural Practices

The farm holdings in the command area vary from 0.10 to 5.10 ha. in extent. While one crop of rice is raised in almost the entire area, a second crop of rice raised in about 40 to 50 per cent of the fields, mainly by those who have wells as supplementary source of irrigation. The agricultural practices closely follow the rainfall pattern. The South-West monsson lasts from mid-June to mid-September and the North-East monsoon from mid-October to December. The land preparation commences in July, after the first few showers of the South-West monsson are received. The average South-West monsson rainfall received is about 400 mm and the North-East monsson rains amount to 700 mm. The remaining 166 mm of annual rainfall is received during the winter and dry weather periods, from January to May. When soil moisture is adequate, paddy seeds are sown broadcast as a rainfed crop to start with. As the crop grows, two to three wettings from the tank are given to a depth of 5 cms. each, when the intervals between the rains are long or after the cessation of the rains, for the crop to mature. Those who have wells raise rice nurseries in advance and transplant the seelings in paddy fields. Local as well as high yielding varieties of rice are cultivated. Transplanted rice yields are about 2.8 tonnes per ha. which are higher by about 65 per cent as compared to broadcast crop (1.9 tonnes per ha.), due to better control of weeds and better fertilization. If the tank water is adequate for raising another crop, the farmers raise the second crop to short duration rice and supplement the water required to mature this crop with well water. Those who do not have wells purchase water from neighbouring farmers who own wells or raise pulse crops with the residual moisture available in the field, after the harvest of the first crop of rice. Thus the tank storage caters to the latter half of the first crop and to the first half of the second crop. Depletion of the tank usually precludes irrigation of a full crop of rice crop during January - May which is the dry season in this part of the country. It is here that the conjunctive use of ground water plays a vital role to supplement

the surface irrigation from the tank. If the period of tank storage is prolonged by minimising the losses and wastage of water, it can be advantageously used for irrigating the entire command area during the first crop and also to increase the irrigated area during the second crop. There is also a large scope for diversifying the cropping pattern and switching from rice to crops that make more productive use of the irrigation water, such as groundnut, pulses and vegetables.

Socio-Economic Conditions

In order to identify the practical problems experienced by the farmer beneficiaries of the tank irrigation system, it becomes necessary to understand the existing traditional farming system of the area and to isolate the major constraints if any, to increase crop production, employment potential and economic improvement of the farming community. A socio-economic survey was therefore conducted to assess their present economic status and the physical, financial and psychological barriers to agricultural development in the command area. This survey was comprehensive and was made with the following broad objectives, with the main emphasis laid on water management practices.

1. Ascertain the currently adopted farm practices and water management techniques;
2. Examine the financial credit requirements for inputs and farm investments;
3. assess the additional support needed to protect the weaker sections of the farming community from being left behind; and
4. Suggest the nature and intensity of extension service needed to motivate the farmers to adopt improved agricultural and water management practices.

For this survey, a structured and pretested questionnaire was used. The study of socio-economic conditions of the farmers covered the following aspects :

i. Distribution of households area and size,
ii. Population, literacy level, occupational pattern and wage rates
iii. Farm, non-farm and financial assets,

iv. Land use and cropping pattern,
v. Adoption of improved agricultural practices and inputs,
vi. Costs of cultivation, income and output-input ratios,
vii. Irrigation and water management practices,
viii. Crop yields and market prices,
ix. Household incomes and expenditure,
x. Financial and credit requirements

The findings on some of the important aspects are summarised below :

1. Farming Households

As per village records, there are 336 householders in the command area in the three revenue villages of Padianallur, Palavoyal and Theerthakarayampattu, owning a total area of 263 ha. of land. Of these, only 305 families are settled in the three villages and they cultivate 238.25 ha. The others are settled elsewhere and are absentee land owners. Hence the study covered only these 305 farming families. The average size of land holdings in Padianallur village is 0.83 ha., while it is 2.32 ha. in Palavoyal and 0.31 ha. in Theerthakarayampattu villages.

The following table furnishes the classification of the farmers and the area owned by them in the different reaches :

Classification of Farmers	Land Holdings			
	Small (Upto 1 ha.)	Medium (1 - 2 ha.)	Large (More than 2 ha.)	Total
No. of farmers and %	249 (81.6%)	45 (14.8%)	11 (3.6%)	305 (100.0%)
Area owned (ha) and % of total extent of land	92.44 (39.0%)	64.55 (27.0%)	81.26 (34.0%)	238.25 (100.0%)
No. of farmers owning lands in different reaches				
Head	43	18	3	64 Nos.
Middle	65	19	3	87 Nos.
Tail-end	141	8	5	154 Nos.

2. Wage Rates

The prevalent wage rates in the command area for different categories of labour and operations are as follows :

Sl. No.	Type of Labour	Name of Operation	Wage per day (Rs.)
1.	Bullock pair with operator	Ploughing	15.00
2.	Man labourer	Land levelling, bunding, sowing etc.	10.00
3.	Man labourer	Non-agricultural operations like construction of wells, heavy earth work excavation etc.	15.00
4.	Man and woman labourer	Weeding, manuring harvest etc.	5.00 - 8.00

3. Land Use and Cropping Pattern

Cropping pattern of an area or a farm depends on several factors, the most important of which are the resources position of the cultivators, rainfall distribution, availability of irrigation facility, market price and demand for the produce.

In the command area of the tank under study with 38 wells in operation to supplement the tank water, rice is the predominant crop grown in about 92 per cent of the area during the first crop season. This is followed by rice again in the farms having wells, while the others grow dry irrigated crops like ragi (millets), groundnut and chillies, or pulses which grow by utilising the residual moisture in the soil after the harvest of the first crop.

The percentage of extents covered by the different crops grown in the command area in all the villages during 1980-81, their average yields and harvest prices are as follows :

Sl. No.	Name of crop	% of area covered (both 1st and 2nd crop)	Average crop yield qtls./ha.		Village harvest price Rs./qtls. (both 1st and 2nd crops)
			1st	2nd	
1.	Paddy (Rough rice)	92	22	27	Local variety 120/-
2.	Ragi (Millet)	3		10-17	High yielding 140/-
3.	Pulses (Black gram)	3		2.5	300/-
4.	Chillies (Red pepper)	1		14-16	800/- to 900/-
5.	Groundnut	1		29	150/-

The main reasons why rice is predominantly grown appear to be that the whole region is a rice growing area; farmers have been traditionally growing this crop and are conversant with the cultivation practices of the crop, there are several rice mills available in the area to process the produce; a large rice market ready to buy the product; and an urban area like the city of Madras close-by to consume the produce. With appropriate extension work there is a good scope to diversify the cropping pattern by introducing crops like groundnut, pulse and vegetables that will make more productive use of water and also give a much higher return to the farmer.

4. Pattern of Inputs

About 77 per cent of the area is covered with high yielding varieties of crops. All the farmers in the command area use Farm Yard Manure (F.Y.M.) as a basal application and chemical fertilizers thereafter. The average use of manure and fertilizer in the three villages during the year 1980-81 was as follows :

Name of village	Average quantity of FYM applied (tonnes/ha.)		Average quantity of chemicals fertilizers applied (Kgs./ha.)					
	I crop	II crop	I crop			II crop		
			N	P	K	N	P	K
1. Padianallur	10.8	Meagre	79	18	18	92	30	30
2. Palavoyal	12.9	Meagre	86	23	23	94	34	34
3. Theerkiakarayampattai	18.5	Meagre	71	9	9	70	12	12

Most farmers adopt plant protection practices, but the degree of protection varies according to their resources.

5. Cultivation Costs and Returns

The following table furnishes the cropping intensity, as well as the costs and returns from cultivation obtained in the different reaches.

Reach	Cropping Intensity	Average for all farmers		
		Cost of cultivation per ha. (Rs)	Gross crop income per ha. (Rs.)	Output/input ratio (Rs)
Head	1.4	2960	3727	1.26
Middle	1.2	2805	3625	1.29
Tail-end	1.6	2737	3961	1.45

6. Irrigation Practices

The study of irrigation practices related to fifty farmers selected by the stratified random sampling method. The area owned by the 50 farmers is 37.44 ha. It is seen from the survey that the small farmers constitute 80 per cent (40 nos.) of the total, while the medium and large farmers constitute 14 per cent (7 nos.) and 6 per cent (3 nos.) respectively. About 12 per cent of the

farmers in the command area own supplemental sources of irrigation like open and shallow tube-wells which command a total area of 94.5 ha. or about 40 per cent of the command area. But in the sample analysed, nine out of the fifty farmers owned wells (2 out of 40 small farmers, 4 out of 7 medium farmers and 3 out of 3 large farmers). Palavoyal village is at the tail-end. One large farmer and his family have five irrigation wells and own 32 ha. of land. Even though the tail-end reach has not uniformly benefited from the Padianallur tank water, it is because of this farm family with a fairly large area under supplemental well irrigation that the picture depicted has become different and the crop income from that village has been the highest.

7. Method of Irrigation

Ninety per cent of the small farmers and 38 per cent of the medium farmers do not have field channels in their land holdings, while all the large farmers have these channels. Totally about 65 per cent of the area lack field channel facilities. Field to field irrigation is practised in these areas which results in wastage of water, besides delays in water supply. This makes the lower down farmers totally dependent on those whose fields are situated above. This method of field to field irrigation also results in loss of plant nutrients and is therefore not liked by most farmers. Three to five irrigations are generally given by the farmers during the first crop season, mostly from tank water, to supplement the rains. During November-December, which is about the end of the first crop season, the tank is generally full. Then the fields situated in the head reach receive seepage water from the tank and are flooded. These farmers do not irrigate their fields then, but resort to surface drainage of their fields. Four to eight irrigations are given during the second crop season when the rains stop. But this irrigation is initially done from the tank and later from the wells, as water lasts in the tank only for about one and a half to two months during this period. The depth of water applied is

5 cm. to 7.5 cm. for each application and the irrigation interval adopted by the majority of farmers ranges from 7 to 10 days.

Even though the tail-end reach generally faced shortage of water from the tank, the large farmers owing wells supplemented the irrigation requirements from the wells and obtained good crop yields. The other farmers in this reach who do not have wells, do not raise a second irrigated crop.

Water charges are collected by the Government along with the annual land revenue, based on the area commanded and not on the quantity of water used. The charge varies from Rs.7/- to Rs.14.50 per hectare depending upon the fertility classification of the land.

Of the several farmers interviewed, 85 per cent expressed dissatisfaction over the present distribution system of field to field irrigation. They desired better regulation to ensure equity, desilting of tank to increase storage capacity and of the irrigation channels to ensure better discharge upto the tail-end. They also desired more distributories and field channels to be provided.

8. Finance and Credit Requirements

The resources of the farmers who are fully dependent upon agriculture for their livelihood are low. Therefore they need credit facilities, as the cost of cultivation has been increasing with the introduction of high yielding varieties and application of chemical fertilizers and pesticides in large doses. But what is important is that these small cultivators are often not creditworthy and hence do not get adequate credit for the required inputs from the financing agencies. It is this category of people who should be helped in a special way, at the same time ensuring that the credit given on personal security is collected without default.

It is seen from the survey connected that only 57 out of 305 farmers revealed that they borrowed money to meet their requirements. Many farmers do not reveal their debit position. Of those who borrowed, 61 per cent were small farmers, 30 per cent medium farmers and 9 per cent large farmers. Of the total amount borrowed, only 15 per cent was by small farmers, 23 per cent by medium farmers and 62 per cent by large farmers. Much of these borrowings of the small and medium farmers was utilised for crop production, while the large farmers used the credit for the purchase of livestock and tractors and also to meet cultivation costs. Cooperatives advanced 40 per cent of this amount while the commercial banks 45 per cent, money lenders 4 per cent, friends and relatives 5 per cent and others 6 per cent.

Forty seven farmers expressed their desire for finance for sinking wells, purchasing livestock and bullock carts and for cultivation. Of these, 31 are small farmers, 15 are medium and one is a large farmer.

Measures Proposed to Improve the System

Based on the findings arrived from the engineering survey, computations made and the measurements recorded, as well as from the socio-economic studies conducted, the following measures are proposed to be implemented to the tank irrigation system.

Watershed

1. Treat the watershed with tree planting to minimise soil erosion.
2. Make improvements in the syphon and feeder channel to increase the water inflow from the intercepted watershed.

Tank Bed

3. Protect the foreshore agricultural lands with appropriate soil conservation measures to prevent silt accretion in the tank.
4. Eradicate the weeds (cyperus spp), to minimise evapo-transpiration loss.

Tank Bund

5. Strengthen and widen the earthen tank bund adequately for use as a cart track as well and stone pitch the water face of the bund, in order to prevent seepage loss.

Appurtenant Structure

6. Repair or reconstruct the irrigation sluices to permit the discharge required and replace the regulation arrangements for effective water control.
7. Provide an additional sluice north of the present sluice No.1 to irrigate the lands which are at present not irriable from any of the existing sluices.
8. Ease the meanders in the alignment and removal of silt, weeds and shrub growth from the main irrigation channels and reshape the channels to hydraulically efficient cross-sections, to prevent seepage loss and to improve the discharge.
9. Lining of the longest main channel from sluice No.2, which carries water to the tail-end reach, so as to prevent seepage loss and to improve the discharge.

The Public Works Department (Irrigation Wing) which is in charge of this irrigation tank has prepared detailed plans and cost estimates for executing the above works as per the suggestions made by this Centre. The execution will be commenced shortly. The State Government will meet the entire cost of these works.

Command Area (On farm development works)

10. Divide the command area under each sluice into convenient blocks of about 10 hectares each, provide laterals and field channels including construction of turn outs, junction boxes, and lined channels, to facilitate conveyance of water to each land holding with the least water loss.
11. Undertake land shaping and smoothening of the fields to the extent necessary.
12. Provide drainage channels wherever needed to dispose the excess water.

These on farm development works will be executed by the State Agricultural Engineering Department for which plans and cost estimates are under preparation by that department in collaboration with this Centre. The cost of these improvements will be initially borne by the Government and recovered from the beneficiaries in easy instalments.

Farmers' Irrigation Committee

An irrigation committee comprising of the farmers from the three reaches of the command area has been organised. They meet

whenever needed to consider the improvements proposed and offer suggestions for modifications if any. This committee will also prepare a rotational system of water distribution for ensuring equitable distribution of water to all the reaches, with the technical guidance provided by this Centre and operate the system through water guides.

Other Supporting Measures

Agricultural extension work will be intensified in this area by enlisting the help of the staff of the State Agricultural Department, who will advise the farmers in modifying the cropping pattern and implementing improved agricultural practices.

Fish culture will be introduced in the tank with the help of the State Fisheries Department to provide for supplemental income.

Further Work Contemplated

Continuous monitoring of the changes that take place in the tank irrigation system including cropping pattern, water distribution and management as well as crop yields will be carried out and recorded to make mid-term modifications if needed. The performance of this irrigation system will be evaluated as suggested by Bhuiyan (2) in terms of its water use efficiency (WUE) estimated by the equation :

$$WUE = \frac{ET + S\&P}{Ir + Rn} \quad \text{where}$$

ET is the evapotranspiration requirement of the crop
S&P is the seepage and percolation rate
Ir is the water supply from irrigation and
Rn is the effective rainfall.

This evaluation will be made for each reach and for each season.

Another socio-economic survey after carrying out the improvement proposed will be made, in order to evaluate the benefits as well as the difficulties experienced and to assess the impact of the improvements.

Policy guide lines for modernisation of other tank irrigation system will be prepared, based on the experience gained.

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ENSURING EQUITY IN IRRIGATION SYSTEMS : A Case Study of a Farmer Group Managed System

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The concept of equity, howsoever defined, is likely to be subjective. The dictionary meaning of equity is given as the quality of being equal or fair. But 'equal or fair', with reference to what? Persons or resources already commanded by certain segments of population? Is it equity among all the villagers or members of groups, peer or otherwise? The concept gets the meaning in the socio-economic milieu of the society with its values, beliefs, traditions, precedents and established principles of social behaviour.

2. In respect of the allocation of water resources for agricultural development, the concept of equity has a wide range of meanings. At one extreme, we have the concept of 'water rationing' whereby the available water resources are allocated on the basis of farming population. Thus in the experiments conducted by Gram Gaurav Pratistan in Pune district the scarce waters are allocated on the basis of half an acre per person in the family, irrespective of the size of the holdings of the family. One of the conditions on the members joining the lift irrigation schemes sponsored by the Pratistan is that they will not irrigate more than half an acre per family member. This is one way of ensuring complete equity in water distribution. However, this principle cannot be operated in surface irrigation schemes. In major and medium irrigation schemes, the operating unit is the area under command and not the families. Equity has to be with reference to areas, though through administrative action, cropping pattern can be enforced to meet the equity standards among the families.

3. At the other extreme, we have situations where the water resources are not quite scarce and/or where there is no demand for all the avai-

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lable waters. In such cases waters could be allocated to all the areas under command, irrespective of the size of holdings. Within this area, equity needs to be defined with reference to crops, soil conditions and capability of the farmers in making good use of the available waters. The innovation of the 'block system' whereby waters are granted to a defined area for a period of 6 to 12 years, irrespective of what happens to other areas, can also be considered as a fair and equitable distribution. Thus, in a difficult water year, the commitments to the blocks would have to be met first, before releasing waters to other parts of the command. This has to be considered equitable, as there would be some annual crops like sugarcane that may be standing and they need to be protected. Even though the denial of waters to other areas for raising foodgrains would be considered iniquitous, prior commitments lend fairness to this practice.

4. A third meaning of equity could be equal water allocation to topenders and tailenders. Within a given chak, it may mean, all the owners of holdings get equal amount of water. Equity can also be said to be satisfied if owners of large holdings are discriminated in favour of small holders. Whatever the meaning, each nuance has technical consequences in respect of discharge capacity, lining, water measurement devices, and water distribution methods.

5. Essentially the concept of equity in the context of irrigation is a dynamic one and is related to geographical accessibility (topography), dependability of water resources over a long period, land ownership and size of holdings, availability and viability of alternative crops, costs of bringing waters and who bears them and the social and economic status of the existing or would be beneficiaries in the given environs.

6. Though not explicitly stated, the equity principle or its absence gets embedded in the design and construction stage of the

irrigation projects. The determination of command area, the likely crop pattern, irrigation intensities, etc., among themselves influence the decisions as to who will get water in what seasons and for what crops. These would be further amended by legislative and administrative actions. Further, the experience has shown that there is a wide gap in what was planned and what has happened. Thus, the Deccan Irrigation works planned in the late 19th century, aimed at providing waters to an extensive area for crops requiring less water. The underlying principle was that in a drought-prone area as many farms as are technically possible should get the waters. However, the experience showed that the waters were not utilised fully and intensive development on a restricted area based on sugarcane resulted. To this extent the equity principle also got modified. Later, the problem was within this restricted area who should get water, for what crop and when.

7. Irrigation researchers are now actively engaged in devising social and technical mechanisms to ensure equity in water allocation consistent with other objectives such as productivity, stability and reliability. The advocacy of Warabandi, rotational water distribution system, etc., is a case in point. In this context, it would be of interest to analyse how equity was ensured in the old, traditional irrigation works, managed entirely by the beneficiaries themselves.

8. Before the advent of modern irrigation works, there was a tradition of building bandharas/weirs on small rivers, rivulets and diverting waters to benefit the nearby agricultural lands. The works were constructed, operated and maintained collectively without any Government support. However, the use of water and agricultural operations were done on an individual basis. This system is even now prevalent in the western side of Maharashtra, especially in Dhule, Nasik and Ratnagiri districts in selected locations. Similar communal efforts are noticed in Goa also, where large blocks of rice fields are irrigated through a common source of waters, collectively developed.

9. In this paper, we propose to examine such a system based in Panzra river basin of Dhule district and analyse how fair water allocation was guaranteed through social organisations and technical devices, as were obtained in old times.

Brief Description of the System

10. The Panzra river originates in Sahydri ranges and after running from west to east for about 88 kms. takes a sharp turn north and after flowing for another 30 kms. meets Tapi river at Thalner. The valley being open and level, the river flows in shallow beds blocked here and there by rocky ledges, of much use in making necessary weirs. The steep gradient of the river combined with the flatness or very gentle cross slopes of the valley help to command large acreage rather easily.

11. There are about 40 bandharas (weirs) on the river commanding an area of about 5000 acres. The Gazetteer of Bombay Presidency (1880) notes that 'tradition attributes the constructing of bandharas to the Musalman rulers and it is probable that many of them date from the time to later Faruqui Kings (1370-1600 A.D.)'.

12. The river has a perennial post-monsoon flow. The Gazetteer observes that river is never known to fail between June and February and that supplies were in excess of demand. However, the situation has changed over the last 50/60 years.

13. Every bandhara has its own Panchas (Committee Members) and Patil (Village Headman) and this Committee looks after the day-to-day affairs. The whole command is divided into Phads (blocks), size of which ranged from 20 acres to 100 acres depending on the topography. In exceptional cases, phads of the size below 6 acres are also to be found. It appears that in the early days, every family has some holding in all the phads. But of late, due to divisions in the family property, only a few beneficiaries have holdings in all the phads.

14. Only one crop would be grown in one phad. Which crops would be planted in the designated phads is decided in an open assembly of the beneficiaries well in advance of the season. The area near the outlet would be irrigated first and then the next one till the tail-end field is reached. This is unlike the Shejpali System now prevalent in major irrigation systems in Maharashtra.

15. After the monsoon season is over, the Panchas prepare a time table for water distribution, which is strictly adhered to. The rotational series forms the part of land revenue record. Those who infringe the discipline are fined by the Panchas. In case, enough post-monsoon flow is not available, broad guidelines are laid down as how to ration the waters.

16. The canal system is maintained by the Panchas for which they are authorised to commandeer the necessary bullock and manpower from the beneficiaries. Those who did not or could not contribute were to pay the equivalent money to the Committee.

17. The rules also provide that the application of water to the field is the responsibility of Patkaris (Watermen) and so farmer would interfere in the process. If the latter has any complaints, he has to report to Panchas. The watermen, inspectors and the watchmen (who are responsible for crop protection) are appointed by the Panchas for the whole command and their remuneration is fixed in kind to be paid by the individual beneficiary at the time of harvesting.

18. It would be seen that the management committees of bandharas are in effect a replica of Irrigation Associations that are now talked about for irrigation development. Their staff is paid in kind, as per the jajmani system.

19. With this background and also the scanty data that are available on the functioning of these groups, let us see how the equity principle in reality operated and the farmers' responses. For purposes of analysis, it would be useful to distinguish equity of water distribution as among the groups and within the groups.

20. As there was no reservoir, bandharas were fed by natural flow or regenerated flow arising from irrigated area upstream. (This situation has changed since early 1970's, when State Government built a medium irrigation dam, upstream of all the bandharas). In view of this, downstream bandharas were dependent on the relative water use upstream, for their water supplies. As a result the elaborate water distribution system (for brevity referred as Phad system) and the control of Panchas on water distribution was quite weak, on the downstream bandharas.

21. Inquiries with the present generation irrigation on Kheda bandhara (which marks the watershed from where river water supplies become uncertain) revealed that to their memory Phad system as prevalent on the upper reaches never obtained in their command. Water management was done by a Committee of six, consisting of Police Patil (village official looking after law and order), Mulki Patil (village revenue and civil official), Talati (revenue record keeper), Havaldar (supervisor of bandhara and canal system) and two Patkaris (watermen). Though there was no control on crops grown, this committee ensured equitable distribution of water within the command and resolved the conflicts backed by the power and influence they commanded as a result of their government positions. It is worth noting that the supervisor was paid Rs.22 per year by the Government in Revenue Department. Additionally, he and the two watermen were paid in kind by the beneficiaries. This system collapsed by 1964, with the abolition of the posts of <u>mulki patil</u> and the supervisor. Since then, in the command of this bandhara and those down below, <u>might</u> generally prevails. Attempts to organise committees on voluntary efforts have evoked a weak response. The problem was further compounded in the late sixties when the State Government declared all these bandharas as first class works and transferred the management to Irrigation Department. This, in itself, should not have made a big difference. But the paucity of funds to maintain the works and the lack of training to the management staff at the lowest level (where it really matters) have led to a stalemate.

22. From an analytical point of view, this behaviour confirms a 'working hypothesis' very perceptively put forward by Dr. Wade (Journal of Development Studies, January 1982). According to him, "water users' associations are unlikely to be sustained (though their initiation by Government is easy) unless many farmers beneath the outlet experience some degree of water stress. If water supplies are abundant in relation to crop water requirement, there will be no need for concerted action. If on the other hand water supplies are precarious, concerted action may be too difficult and cultivators may reduce the area irrigated or switch to less water consumptive crops. To put a number on it, one might suggest that water users' associations will be sustained only where (as a necessary, but not sufficient condition) relative water supply (the ratio of actual water supply at the outlet to crop water requirement) is between 1.2 and 1.5".

23. With precarious water supply and the slow demise of the organisational structure (helped by uncertain water supply) equity principle on these bandharas has been given a go-by. The influential parties in the village utilise the available waters to their best advantage and there is no mechanism to punish the erring irrigator. The junior engineer assisted by ill-trained staff can do very little, especially when his area of jurisdiction is too large for the staff over which he presides.

24. One more aspect of inter-group equity and the likely conflicts that may arise is seen in the bandharas in the upper reaches where the Phad system operates. In quite a few cases, the idle length of the canal from bandhara to the command is about 3 to 6 kms. There are small blocks which can be commanded by the canal in its idle length. In the past, there were occasions when water was diverted unauthorisedly. It is found that in such cases, on an amicable basis, one day in a week has been allotted to such villages for waters in the canal (example Raiwat bandhara).

This is a situation where equity principle was accepted in favour of farmers in the upper reaches because of the topography. Apparently, equity was enforced by the threat of the potential damage that can be done by the upstream farmers.

Intra-Group Problems

25. To ensure equity within the groups, two organisational mechanisms were devised. Depending on their flow, the command area was demarcated. But then the available waters may not be sufficient to irrigate the whole command. Hence the command was divided into kayam bagait (permanent irrigation) and temporary bagait (area which can be given waters, if available). The temporary bagait is always to be found at the tail-end. No sugarcane was allowed in temporary bagait. Sugarcane was rotated among the Phads in kayam bagait only. This device though in a way, iniquitous to the tail-enders helped to maintain the system and reduce conveyance losses. If in any year, excess waters were available they were diverted to temporary bagait. Through this device, conflict with the tail-enders was avoided.

26. Within the group, the question arises, who should get how much of water and when. The water allocation system evolved over the centuries and even now followed has solved this problem without much of a strain. As the different crops have different water requirements, early in the beginning of the monsoon season, an assembly of the beneficiaries specially called decides on the crops to be taken in the phads (blocks). In general, sugarcane is rotated among the phads, other rotational crops being rice followed by wheat, or jowar followed by wheat. Sometimes groundnut or fodder crops are taken. But vegetables or horticultural crops are not taken. Once the cropping pattern is decided, waters are applied by the patkari (watermen) to the fields. No farmer is allowed to water the fields. If there is any complaint, it has to be reported to the Panchas. Besides, the roster of farms to be irrigated in serial order has already been laid down and has attained a sanctity, being a part of the revenue record. No

out-of-turn application is allowed without the specific sanction of the Panchas. This system ensures that all the fields get equitable water supply. Anybody infringing the rules which are known to all the concerned can be fined. Till today such fines have been imposed (less than one per cent cases) and paid by the erring farmers.

27. It would be seen that this system allocates the water equitably among the area. If there is shortage of water in any season, all the command is equally affected. This happens by lengthening the rotation period for every farm.

28. Another way of ensuring the equitable supply is to have a canal with a constant discharge capacity from head to tail. This facilitates quick application of water and helps to reduce the rotational period. (With the building of reservoir, the bandhara farmers are feeling an induced water scarcity).

29. This brief review of the functioning of the traditional farmers' organisations shows how within the technology known to them, and the given social environment, some equity was ensured among the participating farmers by ingenuous organisational devices. It also confirms the hypothesis of Dr. Wade. Though no water measurement is done anywhere on the river, it is known that the well functioning committees above the Kheda bandhara have sufficient water supplies to irrigate the kayam bagait area, in normal years. Whether this system would be extinct under the new water regime is difficult to predict.

Productivity

30. In the Panzra irrigation system, the institutional framework and organisational devices did not pay much attention to the concept of productivity as we now understand it. Application of water was considered ipso facto, a major contributory factor in raising production. More the water, better are the yields. Perhaps this was true in oldern days when there were no fertilisers,

high yielding varieties, pest control methods, etc. Of course the farmers knew from their own experiences and the traditional knowledge handed over from one generation to another, the broad water needs at various stages of crop growth. But then they did not know how to measure water, better water saving methods of applications, yield responses to water use and so on.

31. Further, a collective need to attack these problems was not felt as the cultivation practices were left to individual farmers. If there were differential yields, they were attributed to variations in crop husbandry practices and not to the water use methods.

32. The absence of any research and extension agencies in the area perpetuated the stagnancy in this kind of activity. Statistical data on yields of different crops in the command are virtually absent. However, discussions with prominent farmers indicate that the sugarcane (an important crop in the area) yields are declining. There is however, unanimity among them on the fact that cane yields in the command are much lower (by 40 per cent or so) than those of cane irrigated with well water. They attribute the low yields in the command area to the water scarcity at the bandhara per unit area of sugarcane.

33. Irrigation and agricultural experts who have visited the area feel that the fall in yields could be stopped by avoiding wasteful methods of water applications. If the watermen are trained in new methods and some small investments are made in reconditioning the water delivery system within the command, higher yields can be had with the same amount of water. In any case such programmes can be implemented only with the cooperation of the farmers. At the present stage when there is a feeling of distrust among the farmers about the intentions of Government, no action is likely to be successful, unless they visually see the results.

34. The group management system, evolved over the centuries was mainly directed to ensure fairness among the members of group and thereby impart stability to the groups. Productivity of water

was not their main concern as it was implicitly assumed that it was the main objective which the groups served through elaborately devised management and organisational techniques.

35. It is submitted that this case study may help to formulate guidelines for fostering irrigation association on major irrigation projects, by appropriately modifying the system to suit modern technological developments. Panzra experience suggests that reliability and stability of water at the farm gate, is the key to smooth operation of irrigation association. Equity and productivity can be operated only within these constraints. It is, in principle, possible to operate the system equitably without farmers' participation. But then, it would be costly. Further, as a typical bureaucratic structure vests significant powers on the lower level staff, it is likely to be open to abuses. Irrigation groups, whose members know each other intimately are in a better position to discipline the erring member, once the general framework of operational procedures is known to the beneficiaries in advance and that they know that it is equitable, based on predictable water supply.

15 August 1982

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PLANNING AND IMPLEMENTATION OF MEASURES TO ENSURE PRODUCTIVITY AND EQUITY UNDER IRRIGATION SYSTEMS.

SYED HASHIM ALI

Experience base

This is an Administrator's paper, who has been associated with the problems of Irrigation Utilisation for nearly eleven years in different senior level capacities such as Commissioner of a project dealing with Irrigation and Command Area Development (CAD), Secretary for the Ministry of CAD and Irrigation Utilisation and lastly as Chairman, Commission for Irrigation Utilisation. The areas studied are major command areas covered by the four Command Area Development Authorities in Andhra Pradesh which deal with six Canal systems on Godavari, Krishna and Tungabhadra rivers, five more systems in Andhra Pradesh and some more canal systems in Maharashtra, Gujarat, Punjab, Haryana and U.P. States.

Actual experience in improving irrigation water management to ensure productivity and equity covers a period of five years beginning from 1978-79 when the writer was responsible for all policy level and administrative decisions as the Secretary and Commissioner for Command Area Development in the State of Andhra Pradesh, India.

The Place of productivity and equity in planning and design of irrigation systems:

Before proceeding further some observations on the irrigation systems may be necessary. At the stage of planning and designing of projects[1] the planning and design group of engineers

[1]Based on the evidence gathered as Chairman, Commission for Irrigation Utilisation.

do not generally use the terms "Equity" and "Productivity" in their project reports. The project reports are prepared by adopting an irrigation and cropping pattern which can bring about a favourable Benefit Cost Ratio, to make the project acceptable for the initial sanction. The final expenditure on the project, the area actually irrigated and the cropping pattern adopted by the farmers has generally no relationship with the original projections. It may however be said that between the projects designed in North and South India there is one fundamental difference. The North Indian projects visited by me were either projects originally designed as anti-famine measures or protective projects with a water allowance so low (2.4 to 3.5 cusecs per 1000 acres) that if the water is used for productive irrigation, it will suffice for less than 1/3rd of the cultivable command area. Fortunately in Punjab and Haryana, the tremendous reservoir of ground water has resulted in conjunctive use of surface and ground water not originally planned at the design stage of the project. In fact, in some areas the major share of irrigation is actually being done by Tube Wells and supplemented by surface irrigation although for official purposes, the tube well is augmenting the surface flows.

The Canal design therefore was originally meant to distribute the available water over as large an area as possible to provide protective irrigation to rainfed agriculture. It may therefore be said that these canal systems were designed for equity though this expression is not generally used in the Project Reports. Such a system requires dedicated canal operation and proper allocation of water to farmers without which the top enders in the canal and the top enders under each outlet tend to utilise all available water for themselves. These canals originally designed for continuous flow had a minimum number of control structures which made them rather unsuitable for intensive management of the canal. Rotation among the distributories had to be resorted to when shortages were felt for various reasons such as design assumptions, lack of maintenance, etc. Introduction of Warabandi was therefore necessary both for the reason

of shortages which needed rationing and also for equitable distribution of the rationed commodity.

In South India, where the system of localisation is followed, the localised area is assured the desired amount of water for the designed cropping pattern. Questioned on the basis on which the projects are planned in Andhra Pradesh, the Chief Engineer, Investigation and Planning stated that projects are being planned in A.P. "as productive projects yielding suitable returns as judged by benefit-cost ratio worked for each scheme. They are planned foroptimum yields of crops with supply of water as required for plant growth. There are no protective projects". There is however ample evidence to show that on account of low assumptions for water requirements of crops, seepage and system losses, etc., the projects designed for productive irrigation are incapable of irrigating the localised command area within the prescribed water allocation which formed the basis of the design. As such large tail end areas do not get adequate water to ensure productivity. In projects where the projected command area is being irrigated, the total water used is much higher than the original assumptions. Thus, in effect, both the North and South Indian projects end up with problems of water shortage at the tail-end and abundance at the top. The operation staff which is now being made to operate the canal systems in such a manner so as to ensure reliability, equity and economy in use of water, have to operate systems which were not originally designed for this purpose.

In North Indian systems the quantity of water is so small that the question of using the water for the entire culturable command area for productivity is out of question. The farmer has to irrigate a portion of his entire holding if he has to depend only on canal waters. Equity in distribution has also not been possible because of the absence of control structures which were avoided in original design and are now needed if water has to be distributed equitably.

It is therefore possible that the top-enders may get 4 or 5 irrigations in a season while the tail-enders have to be content with one irrigation if they receive water at all. In the South Indian systems also with the traditional practice of paddy cultivation, projects continued to be designed for continuous flow with minimum controls even when 2/3rds of the area was localised for I.D. crops. The phasing of the project also helped the top-enders to get larger quantities of water while tail-end canal systems were not completed for several years together. As such, the top-enders got used to surfeit of water in the initial stages of the project and when the canal systems were extended to the tail-end areas, there was hardly any water in the canals.[2] A change over to rotational distribution of water was strongly resented by the top-enders. The absence of enough control structures and the long neglect in maintenance because of thoroughly inadequate maintenance grants, resulted in systems becoming inoperable and function only when a much higher quantity of water was allowed to flow.

It may thus be seen that projects not originally designed for equity and productivity when operated to achieve these objectives will necessarily face many problems.

Organised work for Irrigation Water Management of recent origin

Irrigation development consists of two distinct phases. The engineering phase in which the infrastructure consisting of the dam and the conveyance system is constructed. This is followed by the utilisation phase requiring complex multi-disciplinary action for the distribution and allocation of water, land development, agricultural extension, supply of credit, etc.

[2] SYED HASHIM ALI: Water Scarcity and the Role of Operation and Maintenance Administration and Farmers' Organisation. (Seminar at Varanasi, July 1981).

Irrigation utilisation may again be sub-divided into two phases. The intensive development or C.A.D. phase and the agricultural production or maintenance phase which lasts as long as the irrigation supply lasts.

The C.A.D. era began in 1974 when the Government took a policy decision that organised multi-disciplinary work is necessary after the construction phase is over. Command Area Development Authorities were created in some projects and for the first time Government of the State were involved in a work which was previously considered to be an automatic consequence of the completion of the engineering phase and was left entirely to the farmers.

Even after the creation of Command Area Development Authorities the identification of the real problems took several years. Presuming that the canal systems were functioning according to their planned objectives the early emphasis in CADAs was on land development. Farmer reluctance to develop lands in anticipation of water resulted in the land development programme getting slowed down. Another factor for this slow progress was that field channels were considered a part of on farm development and were a charge on the farmer. Credit had therefore to be provided to all farmers within an outlet command (Chak) at the same time. This created many problems as all farmers were not eligible to get bank loans for various reasons. Thus the very process of creating a command area was delayed because water could not be delivered to each farmer. The Government had to take a decision to construct field channels to each survey number (G.O.Ms.No.66, CAD Department, dated 23-9-1978) and then to each holding (G.O. Ms.No.33, CAD Department, dated 29-4-81) at the cost of the project. This momentous decision was the long over due step and enabled creation of a real command area by making a conveyance system, enabling water to reach each holding. The deficiencies in the main system however were discovered when an organised attempt was made to deliver water at each holding. Tail ends of each canal had inadequate and no water supply. The Government

of A.P. had to take several measures to remedy the situation. This paper narrates them very briefly.

Measures taken in Andhra Pradesh

The CAD Department in A.P. was the only separate Secretariat Department dealing with CAD and Irrigation management work. The new Secretariat Department or Ministry was created in August 1974 but in spite of many efforts it has not been possible so far either to appoint a separate Chief Engineer for Irrigation Water Management or to get the Operation and Maintenance staff transferred to the new Ministry. As such, the most important and difficult function of irrigation water management still remains outside the pale of this department and has resulted in problems of co-ordination, and inadequate implementation of orders issued on Water Management by this Ministry.

The Water Management work when taken up by C.A.D. was however done by the engineering staff of the Irrigation Department deputed to the CADAs for systematic land development work and the agricultural extension staff working in the CADAs.

The first step towards water management was taken when in 1978 it was decided to take up Warabandi or Rotational Water Supply among farmers below the outlet at the rate of two minor canals in each canal system in the four CADAs or twelve in all. In the pre-Warabandi survey done by the CADAs it was found that none of the selected minors were capable of delivering the design discharge at every outlet. Maintenance and repairs or improvements to these needed an average amount of Rs.10,000/- per minor canal. Such repairs and improvements were taken up only in one project and there was not much response in other projects. Thus, only two minors out of the twelve selected could really implement Warabandi. This number was increased to 112 in the next year and 350 in the third.

In the year 1981-82 it was clear from past experience that taking up minor canals for Warabandi was not practicable as the

tail-end outlets do not receive reliable and adequate water supply, without which Warabandi is not possible. The C.A.D. Department therefore selected top-end outlets in minors to be taken up for Warabandi. As such the figures given below do not include the number of minors as no minor could be taken up in full for the implementation of Warabandi. The figures of targets and achievements are given below: For the year 1982-83 the area to be covered is shown, the number of outlets is not yet available.

	Target (Cumulative)	Achievement (Cumulative)
1978-79	12 minors	2 minors 240 Ha.
1979-80	112 minors	105 minors
1980-81	350 minors	339 minors
1981-82	3200 outlets	2968 outlets
	80,000 hectares	64,264 hectares
1982-83	1,20,000 hectares	Not yet available.

The deficiencies in the main canal systems which had become visible to the CADAs even in 1978-79 when they took first step towards water management were not fully accepted by the irrigation staff.

As there is no system of monitoring the canal performance to find out whether a canal system is actually functioning according to its original objectives, all the work relating to water management had to be started without sufficient data. The Irrigation staff either did not know the deficiencies in the system or did not take their superiors the Government in the CADA into confidence about the shortcomings in the system. Awfully inadequate maintenance grant which amounted to a little more than Rs.1-00 per acre after deducting establishment cost further aggravated whatever system deficiencies originally existed. But whenever the question of inadequacies, unreliability and inequity of water distribution was discussed in the CADA Board or CADA Working Committee meetings presided over by

the Minister and the Secretary, CAD respectively, any inadequacies in the system were stoutly denied and the CADA had to waste time in trying to collect the information and prove the point. This resulted in an unnecessary and avoidable confrontation and loss of valuable time in rectification of defects.[3]

Introduction of Warabandi brought out the point that no minor was capable of delivering the design discharge at every outlet. Experience in the first two years also showed that the distributories from which these minor canals took off were themselves deficient and as such the Government in CAD Department had to issue another order for Integrated Water Management in the main canal system and below the outlet. This order consisted of the following ingredients:

1) One of the main reasons for the gap between potential and utilisation is the inequitable distribution of water because of unauthorised and over-irrigation by top-enders.

2) Operation of the main canal system without incurring high capital expenditure needs to be given due attention.

3) The Irrigation management policy should aim at enabling all farmers in the command area to get water within the existing limitations of supplies and structural facilities available.

4) Canal Operation above the outlet and water management below the outlet is an integrated process.

5) Each distributory should be taken as a unit and by suitable regulation of supplies into the minors or direct pipes to push water to the lower reaches and make the shortages equally shared by all and any undue advantage or disadvantage on account of location of holdings is eliminated.

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[3]SYED HASHIM ALI: Practical Experiences of Irrigation Reform (1980) Discussion Paper, Institute of Development Studies, University of Sussex and also Water Supply and Management Vol.V, London.

To achieve the above objectives, the Government Order made the Chief Engineer responsible for :

1) Repairs and improvements: taking up minor repairs, desilting, provision of shutters, etc. for pushing the water to the tail-end offtakes.

2) Systematic Canal Operation: If the Majors/Minors are found totally incapable of operation the required improvements and structures should be taken up from the O. & M. budget. Division of the entire length of distributory into convenient zones. The supplies to each zone to be cut of for a certain prescribed time in the week.

3) The operation of this closure may be generally in a sequence from head to tail of the distributory/major.

4) The aggregate capacity of the minors and direct pipes to be closed in each zone should be related to the shortage in the distributory and the carrying capacity of the lower zones.

5) Warabandi: After having ensured a reliable discharge at every outlet, it was decided to take up Warabandi or Rotational Water Supply among the farmers below the pipe outlet for equitable distribution of the available water supply.

6) Staff: Any staff required by Operation and Maintenance Division may be supplemented from the engineering units of the CADA. The Agricultural Extension staff of the CADA should be fully involved in educating the farmers. This work was also taken up in 7 canal system in 105 distributories covering an area of 80,000 acres.

The Chief Engineers and the CADAs were expected to work in close cooperation and were asked to report about the problems in implementation after the season is over. No reports were received from the Chief Engineers about the problems in implementation. Reports about 32 distributories monitored by the four CADAs showed some successes and failures. But this work was done by the Engineering staff of the CADAs without much help from the Operation and Maintenance staff, who had really to implement

this G.O. Later, as Chairman of the Commission for Irrigation Utilisation I had occasion to examine and record the evidence of the concerned Chief Engineers, Superintending Engineers, Executive Engineers and Assistant Engineers of the concerned CADAs. It was clear from the evidence that no one had really applied his mind to this work and the level of implementation in the Irrigation Department was of a low order. One reason for this could be that the O & M engineers who were administratively under the Irrigation Department did not really consider it their duty to implement a G.O. issued by another department which was responsible for irrigation utilisation.

The targets and achievements in Systematic Canal operation in compliance with the Government order on Integrated Water Management are as follows:

	Area to be covered in hectares.	Majors/Distributories taken up for S.C.O.	Actual No. in which implementation was reported	Addl. area brought under irrigation
1980-81	78,380	105	105	Only 12 monitored
1981-82	2,72,974	196	185	24,671 hectares or 12%.*
1982-83	4,18,000	Not yet reported.	Not yet reported.	

*Estimates based on majors monitored.

Systematic Canal Operation over the last three years has shown that it is possible to irrigate larger areas towards the tail ends by curbing over-irrigation by top enders. The level of success in different CADAs was different depending on the intensity of coordination between CADA and Operation and Maintenance staff, the level of understanding of the deficiencies and behaviour of the system by the O & M staff, the craving for water by tail-end farmers specially in drought prone areas, the length of time for which water was denied to them and above all, to the level of dedication of the administrative and technical staff to the ideal of Integrated Water Management.

The administrative arrangements for coordination, motivation and education of farmers and implementation and monitoring were different in the four CADAs. The emphasis everywhere was to deliver water to the tailenders on a reliable basis which is a condition precedent to Rotational Water Supply below the outlet.[4]

No detailed research has been done on the effects of Integrated Water Management and the only material available is reports by Administrators based on which I wrote a paper[5] and a report by the Ford Foundation on one Distributory in which the CAD Department, Irrigation Department, the Water Technology Centre and Ford Foundation had collaborated.[6] More detailed research would be necessary to evaluate the effects of this administrative measure.

Farmers' Organisation

Another informal administrative measure which has not yet been formalised by the issue of a Government Order is the formation

[4] SYED HASHIM ALI: "One Season of Integrated Water Management" Seminar Paper, Coimbatore, 1981.

[5] Ibid.

[6] Roberto Lenton, Ford Foundation, 1982.

of Pipe (Outlet) Committees of farmers under each outlet. The first Committee was formed by me after the completion of systematic land development under one Pipe outlet on total boundary realignment basis in Pormalla village under Sriramasagar project in the year 1975, to organise water distribution by themselves. Following this, Pipe Committees have been formed under all pipe outlets after the field channels construction was over and Warabandi was introduced. The comprehensive legislation on Command Area Development however gives them a statutory status with well defined functions. (Appendix 4).

Simplification of procedure for construction of field channels

One of the main constraints in construction of field channels was the lengthy and cumbersome land acquisition procedure. To simplify this a section in the CAD legislation enables the engineers to construct field channels by a very simplified procedure which enable him to enter upon the land and construct field channels as if all legal procedures under the Land Acquisition Act have been complied with (Appendix 5).

Unfortunately this Ordihance which was promulgated in January 1982, has lapsed and has to be taken up again.

It may thus be seen that the Government of Andhra Pradesh has taken some basic measures to improve proper distribution of water to ensure equity and productivity. These measures are

1) Construction of field channels at Government cost upto each holding (Appendix 1).

2) Simplification of procedure to ensure early construction of field channels (Appendix 2).

3) Enforcing Integrated Water Management by Systematic Canal Operation (Appendix 3) to ensure reliable delivery of water at each outlet and by enforcing Warabandi for equitable distribution among the farmers. (Appendix 6).

4) Formation of Pipe Committees for Water Management and Maintenance of the irrigation system below the pipe outlet. (Appendix 4)

Difficulties experienced:

The implementation of these measures was a difficult task as all these measure were intended for bringing about a change in procedures and attitudes and faced resistance at all levels.

The Irrigation Operation and Maintenance and CAD staff was under different Ministries and there were problems of coordination. This problem could be tackled by delinking Operation and Maintenance from construction work and making it a part of the agricultural production process by bringing both these functions under one Ministry or a single line of command.

Irrigation systems were found incapable of being properly operated. A minimum level of maintenance is necessary to introduce water management. The strength of the O & M staff was found inadequate to take up intensive water management and requires strengthening and conversion into a multi-disciplinary and specialised organisation.

There were no Operation and Maintenance Manuals. Every distributory behaved differently under intensive management. Separate O & M Manuals are necessary and have to be corrected and improved for two to three years before being finalised. Water Management extension among farmers was found deficient and requires special attention by the Agricultural extension service which in turn needs training. Mere engineering measures will not be effective. Water Management to achieve equity and productivity requires involvement and close and continuous interaction of many disciplines. Legal, political and administrative backing is necessary in addition to full involvement of farmers in the implementation of these measures.

Improvements and change in strategy required

Having spent several years in identifying and solving problems connected with irrigation utilisation, it is possible to say now that CAD work suffered from certain wrong assumptions from the beginning and therefore a lot of time and energy were wasted in initiating programmes such as land development, before ensuring delivery of water at the farm. After some years of undivided attention on land development, it was realised that field channels for delivering water to the farmers are a pre-conditon for enabling farmers to take individual or collective action needed for water utilisation. The step for Warabandi for equitable distribution of water below the outlet was taken up without first ensuring a reliable discharge at the outlets and thus if the sequence of action in the CAD programme had been corrected, the pace of development would have been much faster. Based on the experience in the past, and to ensure a faster pace of development, equity in distribution and increase in productivity, the correct sequence may perhaps be as follows :-

1) Delivery of a reliable, adequate and timely supply of water at the outlet by intensive main system management.

2) Construction of an appropriate distribution system bringing the water to each holding.

3) Allocation of water to each farmer.

4) Formation of Pipe Committees to enforce allocation and to maintain the system in the Chak.

5) Water Management Extension to enable the farmer to make use of the allocated quantity in the most efficient manner in his holding.

6) Appropriate land development and adoption of the correct irrigation techniques for optimising the use of allocated water.

7) Intensive Agricultural Extension for adoption of irrigated agriculture and providing all the inputs, facilities and services such as long term and short term credit, seeds, fertilizers, pesticides, storage, marketing and communication facilities, etc.

8) Action research to determine the success or otherwise of measures taken for equitable distribution of water and their effect on productivity.

This research would also be indirectly beneficial in evaluating system performance. The data thus made available would be of great use in planning and designing future projects which are able to achieve equity with productivity, an ideal which is not generally achieved in most projects.

COPY OF

Appendix 1

GOVERNMENT OF ANDHRA PRADESH

Abstract

FIELD CHANNELS - Irrigation projects, Major, Medium and Minor Construction of field channels at project cost by project authorities upto each Survey Number including drops and distribution boxes, etc. in on-going and future projects- Consolidated orders - Issued.

Command Area Development (I) Department

Dated 23rd September 78
Read the following :-

1. G.O.Ms.No.827, P.W.(Irr-VI) Dept. dated 13-7-1973.
2. G.O.Ms.No.41, C.A.D.Department, dated 9-6-1977.
3. G.O.Ms.No.65, C.A.D.Department, dated 22-8-1977.
4. From the Chief Engineer, Irrigation & Power Dept. letter No.HLC/II.SO.I/46837/77-1 dated 14-9-77.
5. From the Chief Engineer (Major Irrigation & General) letter No.HLC.II/48637/77-1 dated 29-11-1977
6. From the Chief Engineer (Medium Irrigation) letter No.HLC.II/SO.IV/55465/77-9 dated 6-5-1978.

O R D E R

Field channels play a vital role for achieving speedy development of Command areas under Major, Medium and Minor Irrigation projects in the State, and it would be expedient to execute them along with other civil works of the projects, such as canals and distributories, etc. With this end in view it was ordered in the G.O.first read above that in future, the field channels under Irrigation projects should be excavated at project cost upto 25 (twenty five) acre limit or the last survey number. It was also ordered that the Revenue Department should take into account the cost of provision of field channels, while next considering the proposals for enhancement of the water rates. In spite of the above orders, no significant strides have been made in regard to development of Command areas as these orders did not enable the land holders in each survey number to draw water from the Irrigation channels. Besides large gap between creation of irrigation potential and actual utilisation there is every need to avoid field to field Irrigation for optimum utilisation of water and introduction of rotation system (Warabandi) for equitable distribution of water.

2. In view of the important role played by field channels for the accelerated development of commandareas, and in view of the need for introduction of rotation system for equitable distribution of water, the G.O.s second and third read above had been issued as Governments were of the considered view that utilisation Irrigation potential is created only when field channels are constructed upto each survey number. There has however been a slight ambiguity in regard to the application of the above orders, and different proposals were also received from Chief Engineers and others seeking clarifications. To remove the ambiguities, the Government have examined the matter and in modification of the orders issued in the G.Os. second and third read above, issue the following comprehensive orders :-

1) The field channels should be constructed including related structures such as drops and distribution boxes upto the commanding point of each Survey No. or 5 Ha limit whichever is less in all on-going and turure Major, Medium and Minor Irrigation projects in the State.

2) The cost of construction of field channels indulging related structures should be a charge on the project funds and included in the revised estimates of the on-going projects and in the estimates of all future projects.

3) Priorities should be accorded to the on-going projects, where the distribution system has already been completed and the Irrigation potential created remains unutilised due to lack of field channels.

4) The field channels should be sligned along the ridges or contours as the case may be but where the individual holdings get sub-divided into small bits on this accout the field channels may be constructed along with field boundaries.

5) The design of the field channels should cater to the requirements of turn system (Warabandi) in the pipe outlet Command area (chak).

6) For proper water management and for implementation of the turn system of Irrigation within the canal system and to ensure supply of water to the tailend ayacut it is necessary that every pipe outlet is provided with control arrangements.

7) The maintenance of field channels in the chak including masonry works shall not be the responsibility of the Irrigation Department and they shall be maintained by the farmers themselves.

8) The effect of bringing the field channels to each Survey No. and the pace of development should be reviewed every two years, especially in Command Area Development areas where there is a full complement of Command Area Development staff.

9) The Irrigation Engineers should intimate the creation of potential immediately, after the construction of field channel under each pipe to the District Collectors in all Command areas and the Administrators of the concerned Command Area Development Authorities in the select Command areas to enable them to take up follow-up action for land development.

10) The Government also direct that in the case of the command areas where the Command Area Development Authorities have been formed and where the land development staff have already designed the Irrigation system in the chak, the Irrigation Department shall follow the design prepared by the land development staff of the Command Area Development Authorities to the extent of construction of field channels upto the commanding point of each Survey No. Where the field channels are being excavated or already excavated by the Command Area Development Authorities, the expenditure shall be chargeable to the project concerned.

3. This order issues with the concurrence of Irrigation & Power Department - Vide their U.O.No.2606/NSP.I/77-11 dated 21-11-77 and Finance & Planning Department - vide U.O. No.3579/FSP dated 25-11-1977.

(By Order and in the name of the Governor of Andhra Pradesh)

SYED HASHIM ALI,
Secretary to Government.

(True Copy)

Appendix 6

Government of Andhra Pradesh

Abstract

COMMAND AREA DEVELOPMENT DEPARTMENT - Warabandi Programmes in the select Command Areas - Implementation of - Orders - Issued.

Command Area Development (II) Department

G.O.Ms.No.68 Dated : 16-9-1980

Read the following:-

1. G.O.Ms.No.66, C.A.D. Department dated 23-9-1978.
2. G.O.Ms.No.58, Command Area Development Department dated 5-8-1980.

ORDER

For obtaining maximum returns from an Irrigation project, Utilisation of Irrigation waters in the entire command areas, under every pipe (outlet), is very essential. At present, there has been inequitable distribution of water in most of the Command areas under a pipe (chak) either due to unauthorised conversion of I.D. into wet or over irrigation by top-enders, among other factors.

2. To obviate this, Government consider that a methodology of rotational water supply (Warabandi) for providing Irrigation water for the entire chak should be evolved and implemented without incurring any high capital expenditure. In this programme of Warabandi the operation and maintenance staff of the Project should ensure the supplies of designed discharges at each pipe and the Command Area Development Authority should coordinate the water deliveries and utilisation and assist the farmers in implementing the Warabandi programme. The supply of water during the allocated time in the Warabandi programme to each farmer will motivate the farmer to use the "water time" allotted to him to his best advantage as he can pre-plan his agricultural production activities. It will also enable full utilisation of Irrigation potential in the entire command area.

3. The main elements of Warabandi programme are :-

i) Ensure that the designed flow of water is available at each pipe.
In case this is not possible in spite of operational and engineering improvements, the available discharges have to be distributed,

8) When the land through which the field channel passes is not benefited therefrom, the owner of such land shall be paid an amount calculated at the rate at which the land required for construction of field channel at the nearest point from which the pipe outlet has been taken, has been acquired.

Provided that where a question arises as to whether the amount payable under this sub-section corresponds to the market value of the land, it shall be referred to the District Collector, whose decision thereon shall be final.

9) Notwithstanding that the cost of construction of the field channel is met by the Government, the responsibility for maintenance of the field channel shall vest with the pipe committee; andthe beneficiaries of the field channel shall not acquire any right other than that of user only.

10) Any person, resisting the exercise of the powers, of having control over the property fails to give all facilities for their being exercised, shall be deemed to have committed an offence under section 188 of the Indian Penal Code, 1860.

(True Extract)

Appendix 5

Section 13 of Ordinance on Command Area Development.

Construction of field channels :

13. 1) Whenever it appears to the Government that the constructionof field channels is expedient for the supply of water to the lands immediately after or simultaneously with the availability of water in the main irrigation system, the Government may, by notification, declare the command area under an irrigation system or project or source for the purpose of applying the provisions of this section.

2) On the issue of the notification, the Land Development Officer, shall have power to enter upon any land and make survey of such land to determine the most suitable alignment for the field channel so as to convey water to every land under a pipe outlet and mark out the land which, in his opinion, is necessary for the construction of the field channel.

3) The Land Development Officer shall thereupon publish a scheme in the prescribed manner giving details of the lands through which the field channel is proposed to be taken and specifying the areas and the names of persons likely to be affected.

4) Every person likely to be affected may submit a petition to the Land Development Officer stating his objections, if any, to the proposed construction of the field channel within fifteen days of publication of the scheme. The Land Development Officer shall finalise the scheme after considering the objections, if any, and publish it in the manner prescribed. An appeal against an order of the Land Development Officer may be filed before the District Collector within fifteen days of the publication of the scheme.

5) The Land Development Officer shall, after the expiry of the period of appeal, or where an appeal is filed before the District Collector, subject to the result of appeal, cause the field channel to be constructed so as to convey water to every land under a pipe outlet.

6) Notwithstanding anything in the Land Acquisition Act, 1894 it shall be lawful for the Land Development Officer to enter upon lands required for the construction of field channel and to cause construction of the field channel as if a declaration had been made by the State Government for the acquisition thereof under section 6 of that Act and as if the State Government had thereupon directed the Collector to take order for the acquisition of such land under section 7 of the said Act and as if the State Government had issued orders for immediate possession being taken under section 17 of the said Act.

7) The Land Development Officer shall, after the construction of the field channel, fix the boundary marks in the prescribed manner and thereupon the ownership of such land shall vest in the Government.

Appendix 4

Appointment of a Pipe Committee and its functions. Section 5 of the Ordinance of Command Area Development :

1) The Irrigation Officer shall have the power to appoint, a pipe committee for each pipe outlet, consisting of a president who shall be the chief executive authority of the pipe committee and other members, who shall be the land holders under the pipe outlet.

2) The number of members of the pipe committee and their term, the procedure to be followed at the meetings of the pipe committee, the powers and duties of the president and the disqualifications and removal of the president and members thereof, shall be such as may be prescribed.

3) The pipe committee in which the power to administer and supervise the irrigation system under the pipe outlet concerned vests, shall be responsible to perform the following, among other functions, namely :-

a) the construction, maintenance, repair and upkeep of the irrigation system under the pipe outlet at the cost and expenses of the land holders;

b) to carry out obligations on behalf of the land holders, if the land holders fail to do so, and recover costs, thereof from them in such a manner as may be prescribed;

c) to enforce warabandi and to regulate supply of water for irrigation to each land holding by turns or rotation according to the time schedule approved by the Irrigation Officer;

d) to regulate and control water supply for irrigation by volumetric measurement in the manner specified by the Irrigation Officer;

e) to prevent unauthorised and unlawful use of water for irrigation;

f) to supervise the irrigation system with a view to preventing waste of water and damage to the system;

g) to perform such other functions as may be prescribed.

(True Extract)

5. For implementing the Integrated Water Management programme, the Chief Engineers should ensure that - -

i) any minor repairs, desilting, provision of shutters etc. for pushing the water to the last minor/outlet should be taken up and completed before the Kharif season. This is essential for building up the required confidence among the farmers.

ii) if the majors/minors are found totally incapable of operation in the preliminary survey before Integrated Water Management is taken up, the required improvements in the structures etc., should be taken up and the Chief Engineers should ensure that the expenditure is limited to the minimum and after the experience in Kharif, further improvements which are absolutely necessary should be undertaken. This expenditure should be met within the budget grant under 'O & M' available with the Chief Engineers.

iii) Any additional staff if required by O & M Division on the Engineering side may be supplemented from the Engineering units of the CADA. The Agricultural Extension staff of CADA should be fully involved in educating the farmers.

6. During Kharif 1980, Integrated Water Management shall be taken up in the projects and distributories/majors specified in the schedule given in the 'Annexure' and shall be continued in future seasons.

7. This order issues with the concurrence of Irrigation and Power Department and Finance & Planning Department - Vide their U.O.No.370/EP/80 dated 11-7-1980.

(By Order and in the name of the Governor of Andhra Pradesh)

SYED HASHIM ALI,
Secretary to Government.

To
xx xx xx

A N N E X U R E

Details of Majors/distributories wherein Integrated Water Management should be introduced during Kharif 1980.

1.	Nagarjunasagar Left Canal Command area.	85 major/distributory.	
2.	Nagarjunasagar Right Canal Command Area.	5 " "	
3.	Tungabhadra Project command area		
	a) K.C. Canal	3 majors	distributory.
	b) High Level Canal	3 majors	
	c) TB Low Level Canal	2 majors	
	d) Rajolibanda Diversion scheme	3 majors	
4.	Sriramasagar project area	4 majors	
	Total :	105 major/distributory.	

(True Copy)

Appendix 3

COPY OF

GOVERNMENT OF ANDHRA PRADESH
Abstract

COMMAND AREA DEVELOPMENT - Integrated Water Management Programme in Project command areas - Implementation of - Orders - Issued.

Command Area Development (II) Department.

G.O.Ms.No.58 Dated 5th August 1980.

ORDER

In most of the Irrigation projects, there is considerable gap between the localised area and the area actually irrigated under each major distributory. One of the many reasons for this gap is the inequitable distribution of water in the system, because of unauthorised and over irrigation by the top enders.

2. Government consider that improved operation of the canal system without incurring high capital expenditure on modernisation, needs to be given due to attention in Irrigation Management. Irrigation Management policy should aim at enabling all the farmers in the command area to get water within the existing limitations of supplies, and structural facilities available. The Government have, therefore, decided to introduce Integrated Water Management above and below the outlet. This has to be done by taking each distributory/major as a unit, and by suitable regulation of supplies, into the minors or direct pipes, to push the water down to lower reaches, so that the shortages, if any, in the system are equally shared by all, and any undue advantage or disadvantage on account of location of holdings is eliminated.

3. The main elements in Integrated Water Management are :

1. Division of the entire length of the distributory/major into convenient zones.
2. The supplies to each zone have to be cut off for a certain prescribed time in the week by closing the minors, and the direct pipes in each zone.
3. The operation of this closure may be generally in a sequence from head to tail of the distributory/major.
4. The aggregate capacity of the minors and direct pipes to be closed in each zone should be related to the shortage in the distributory/major and the carrying capacity in the lower zones.
5. Introduction of Warabandi for equitable distribution of Water among the farmers below the outlet.

4. The organised system of rotation in the main system has to be finalised in full consultation with Command Area Development Authorities and with the participation of the farmers to enable the tail-enders also to take full advantage of this arrangement.

3. Under the new pattern, Central assistance to the extent of 25% of the cost of earthen (Kuchcha) field channels with related structures and lining of some vulnerable reaches would be available as a grant. (Another 25% would be available as a loan repayable over a period of 15 years or as may be prescribed from time to time). The State Government would have to match this with a similar contribution from its own (budgetary) resources. In other words, half the cost of construction of field channels would not be recoverable from the farmers. The other half of the cost would be ultimately recoverable from the farmers over a period and in a manner to be left to the discretion of the State Government.

4. The State Government have carefully examined the matter taking into consideration the cost involved in taking the field channels beyond 5 hectares limit and the financial assistance offered by the Government of India. The Government hereby order that field channels with related structures should be constructed beyond the 5 ha. limit and upto each individual holding within the outlet command at project cost in all on-going and future Major, Medium and Minor projects in the State. The orders in para 2(i) of the G.O. first cited shall be deemed to have been modified to this extent.

5. The Chief Engineers should take necessary action for provision of funds for construction of field channels with related structures upto each individual holding within the outlet command in all on-going and future projects as already instructed in the reference fourth read above.

6. At present, only four commands in Andhra Pradesh, Nagarjunasagar Right Canal, Nagarjunasagar Left Canal, Sriramasagar project and Tungabhadra project are included in the Command Area Development programme and are eligible for Central assistance towards the cost of constructing field channels upto each individual holding. The Chief Engineers/Command Area Development Authorities Administrators should maintain separate accounts for the expenditure which is eligible for 25% grant and 25% loan assistance from the Government of India and furnish the details to the Government in the Irrigation and Power/Command Area Development Department so that the assistance can be drawn from the Government of India by filing the claims etc., in the prescribed form.

7. This order issues with the concurrence of Finance and Planning Department - Vide their U.O.No.876/F.III-1/80-1 dated 23-12-1980.

(By order and in the name of the Governor of Andhra Pradesh).

C. Srinivasa Sastry,
Secretary to Government

To
Engineer-in-Chief.

xx xx

xx xx (True Copy)

COPY OF

Appendix 2

GOVERNMENT OF ANDHRA PRADESH

Abstract

FIELD CHANNELS - Irrigation projects - Major, Medium and Minor Construction of field channels including related structures such as drops, distribution boxes etc., at project cost by project authorities upto the commanding point of each holding in all on-going and future projects - Modified orders - Issued.

Command Area Development (I) Department

Dated 29th April, 1981

Read the following :-

1. Go.O.Ms. No.66, CAD dated 23-9-1978.
2. From the Govt.of India, Ministry of Agricultural letter No.11-10/80-CAD dated 22-4-1980.
3. From the Govt. of India, Ministry of Agriculture letter No.11-60/79, dated 14-5-1980.
4. Govt.Memo.No.2273-Irrign.VI-2/80-1 dated 4-9-80.
5. Govt.Memo.No.4253/Irrign.VI-1/77-2 dated 6-10-1980.

ORDER

Absence of field irrigation channels within the outlet command is one of the important factors responsible for under utilisation of irrigation potential created in Irrigation projects. To overcome this deficiency, orders were issued in the G.O.first cited, inter-alia, to the effect that the field channels including related structures such as drops and distribution boxes should be constructed upto the commanding point of each survey number or 5 hectare limit, whichever is less, in all on-going and future major, medium and minor irrigation projects in the State.

2. The Government of India, Ministry of Agriculture in their letter second cited have emphasised that construction of field channels from the irrigation outlet upto each individual holding is the most important item for ensuring some of the basic objectives of the Command Area Development Programme, like full utilisation of irrigation potential, efficient water management, etc. The Government of India have also offered assistance according to which, for all the projects included under the Command Area Development Programme, Central assistance on a matching basis would be available for constructing field channels from the pipe outlet upto each individual holding.

ii) Ensure supply of water to all the farmers in a chak irrespective of the location of their holding.

iii) Provide equal volume of water to each acre of the Command area under a pipe irrespective of the location by allocating a flow time.

iv) Help the farmers to know in advance the day, period and volume of Irrigation water, allotted to their fields.

v) Develop consciousness amongs farmers so that they begin to realise that Irrigation water is a scarce resource and to motivate them to use their share efficiently to maximise production.

vi) Help in fuller and better utilisation of Irrigation water and improve Irrigation efficiency and minimise waste.

vii) Bring about disciplene in water use and eliminate unauthorised or illegal irrigation.

4. In view of the importance of equitable distribution of water and its timely supply, Government have decided to implement a Warabandi programme. For implementing the Warabandi programme, the following should be ensured.

1. Farmers are to be consulted before developing a proper layout of field channels network particularly the location of distribution boxes for each Irrigation zone.
2. Formation of Irrigation Zones and identification of farmers in the zones in consultation with the farmers.
3. Preparation of time schedules for each Irrigation Zone and individual farmers in consultation with them taking into consideration the length of field channels, flow velocities and transmission losses.
4. Exhibiting on display boards the scheduling of Irrigation Variation to this schedule within the zone can be made by the Zonal Representative in consultation with the farmers in that zone.
5. Assisting selecting zone representatives and formation of pipe committees, and their leeaders. The pipe committees should be induced to take over the field channel system to ensure the safety of the structure and for the operation and maintenance of the system.

The Warabandi programme shall be taken up in the select Command areas and will be gradually extended to other command areas.

5. This order issues with the concurrence of Irrigation and Power Department.

(By Order and in the name of the Governor of Andhra Pradesh)

SYED HASHIM ALI,
Secretary to Government.

To
The Chief Engineers of select Projects.

xx xx

(True Copy)

12

PAPER FOR THE SEMINAR TO BE HELD AT GIRI INSTITUTE, LUCKNOW IN THE SEPTEMBER, 1982.

19

IMPORTANCE OF OPERATION MAINTENANCE AND FLEXIBILITY IN LARGE IRRIGATION SYSTEM FOR IMPLEMENTING EFFECTIVE WARABANDI TO ACHIEVE EQUITY AND PRODUCTIVITY.

BY

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...

In large irrigation projects the water is made available simultaneously from different points to the cultivators and from each point many cultivators are to receive water. To ensure this, it is necessary to have an operational plan based on scientific lines. In the absence of such a plan, there is bound to be confusion and conflict among the farmers.

2. In India, most of the old large irrigation projects are functioning from ages and in almost all these old irrigation projects the cultivators evolved their own system of drawing water which often results in inequitable distribution. Due to social pressures and political will some farmers, though their lands are localised, are not able to obtain water and consider that it is not worthwhile or advisable to register even their protest.

3. Population pressure, scarcity of food and arable land, high investment in development and maintenance of irrigation project; new technologies in agriculture which depends upon assured water supply and its judicious use; two together are responsible for the active interest from the Government as well as from the farmers side, to utilise water from irrigation projects in a more effective manner.

4. With the introduction of high yielding varieties and the setting up of Command Area Development Authority, a multi-disciplinary agency, in coordination with other agencies and institutions, farmers no longer consider agriculture as a mere way of life and a means of subsistence, but prefer to go in for high yielding varieties with a view to get enhanced incomes. This switching over of agriculture as an economic activity with heavy investment for land development and other inputs enhances the importance of irrigation.

Contd...2.

5. Even the small and marginal farmers hitherto silent spectators, due to changes in the very political structure are now keen to fight for their rights to enjoy the economic benefits of irrigation and claim their right to water supply. The concept of equality in all walks of life and the need for maximising production has made the Government evolve a method of providing assured water to all the fields in the command irrespective of location and holdings.

6. The Warabandi system which was introduced in Haryana, Punjab and in most parts of Uttar Pradesh in the past to avoid conflicts and to enforce discipline , no doubt served its purpose and stood the test of time but it appears to be ineffective to solve the present problems of irrigated agriculture. In the old system, time was allocated for taking over water on the basis of holding. It had no relevance with the actual demand for water or its usefulness for the crops. This system of water distribution no doubt results in fixing the turns and timings of watering as per the size of land holding, adversely affected the small and marginal farmers, chiefly, when from an out-let a big area is to be irrigated in a limited time, and has benefitted only the big farmers.

7. It was noticed that in Chak, say of 400 Acres, big holders having 60 Acres or above were allotted more than 25 hours a week to irrigate their lands while small farmers were allotted hardly 4 to 5 minutes a week with their holding of 1/4 Acres or so, no doubt with a big flow of about 4 cusecs, which in fact also works adversely, as it is impossible for them to handle the same. The net result was that in most of the cases, the small farmers could not utilised the irrigation water at all. Further, even among the big farmers though the time allotted may be equitable in the light of the holdings, the quantum of water differed depending upon the location of the fields, as no allowance was given for the seepage losses and travel time. In addition to this, in most of the projects delivery systems were directly from the rivers which had fluctuating flows.

Contd...3.

8. With the building of reservoirs at different points and in some cases the entire distribution system dependent solely on the reservoir, the problems of un-controlable flows have been solved to a great extent.

9. The present agricultural technology fixed up very clearly the water requirement of the crop at its different stages of growth for the optimum yield and also the quantity required at critical stages to avoid bad effects of dry spell in times of water scarcity. As such, at present with a view to equity and the production of maximum yields; Project Managers must meet the crop demands by adopting an appropriate operational strategy. Therefore, there ought to be operational mannuals for different cropping patterns applicable both in times of sufficient water to meet the demand and also when water is barely enough to meet the requirements of plants at critical period.

10. Operational plans should be based on realistic knowledge with regard to the system efficiency and the seepage and evaporation losses in different parts of the irrigation system. This is to be worked out carefully and schedules fixed to ensure, that every farmer receives his allotted share in time.

11. The size of pipe outlets and their location on the net-work of irrigation, the field channels and the distribution boxes on them, are to be designed and executed very carefully.

12. This means the old concept of providing of water for large area and allowing farmers to have their own field channels is to be replaced. The Government net-work of irrigations should not end at the pipe outlet, but should reach the farmers' field. Further, an adequate number of controls, regulators and other structures to divide and push the available supply not only above the pipe outlet but below it are required, so that from every point of the net-work deliveries can be effected as fixed for different stages of crops by the agricultural experts, upto the fields of each farmer by the operation of the regulators.

Contd...4.

13. Such a systen solves the tail-end and water logging problens. There will also be a lot of water saving, and the efficiency of the inputs used chiefly fertilizers, will increase renarkably. The warabandi introduced in Sreeransagar Project and its close evolution indicates that the operational flexibility of the project is the outcome of the flexibility of all net work components connecting the head work to the farners' field.

14. Each conponent of the irrigation systen has its own specific hydraulic and net-work problens. Unless and until each problen they (operational engineers) carefully studied and solved, the systen will fail to function effectively. Lot of planning is necessary for making warabandi really effective. The entire systen has to be studied and its defects renoved either by physical inprovenents of the systen or by operational innovations and only then it is possible to have deterninetal flow rate at a pre-deterninetal tine interval, and on this basis only can warabandi sche-dules be prepared and rotational tine table for the distributories and ninors fixed by the Governnent Officials. Once the confidence is created anong the cultivators that, if they strictly adhere to the tine table given to then, they will receive the quantun nost suitable for giving then the highest yield, full cooperation for naintenance and running of the systen will be available fron the farners.

15. Once the irrigation systen is nodernised with operational flexibility deliveries can be adjusted, to neet the farners changing and progressive needs during the project life. As no large irrigation systen can be operated to neet the denands of individual farners, it becones incunbent on the operational wing to devise and select the appropriate operational strate-gies to neet the average denands of the collective groups of cultivators.

Contd....5.

16. Once the farmers are aware that the irrigation system can provide a particular quantum in a particular period at the Chak outlet and that farmers below that Chak outlet are to receive equal flows, then they utilise the same by mutual adjustment within the group or they may adjust their crops to get the best economic return from the utilisation of available water.

17. To this day in most of the irrigation systems, due to limited net-work capabilities of the irrigation project, and the absence of clear objectives to deliver equitable, assured and timely water supplies to farmers, the up-stream cultivators are receiving more than their fair share of water, while the tail-enders are suffering from severe shortages. These anamolies are not only noticeable below the Chak, but in the entire system i.e., in the upper reaches of the main canal, distributories and minors, more water is available than the middle reaches and still less in the lower reaches and in some cases no water reaches the tail-end. To have a system wherein every farmer irrespective of location receives equal quantum of water the measuring device in the entire system to ensure proper flow of allocated water is a must. An adequate number of controls and regulating structures are required at suitable points to divide the main canal flow so that every distributory sub-distributory and minor receives designed discharges. In a large irrigation system in absence of the measuring devices and cross regulators, a little increase or decrease in the head of the upper reaches effects abnormal increase or decrease at the field level.

18. Once the flexible system and operational efficiency are developed the problem remains of utilising the water below the pipe out-let. It is un-thinkable with the present strength of staff, incharge of water management to provide and control the distribution of water upto the farmers' fields. Further, the maintenance of the net-work below the Chak outlet is not possible departmentally. As such, the involvement of cultivators for running the same is a must. However, efficient a system

Contd...6.

may be, the supply needs of individual farmers cannot be met, if it is not handled by the beneficiaries themselves. The good relations between irrigation authorities and the Users, that is farmers and their agreeing to abide by certain rules and procedures laid down jointly is also a must. The technology employed for delivering water below the pipe outlet can be designed and executed with the common understanding of farmers, agricultural technologists and engineers, well versed in small hydraulics. The schedules for watering can be fixed after due data collection with regard to water holding capacity of field, seepage losses and travels time from one block to the other, within the pipe outlet. Groups can be constituted so as to adjust the water within the groups matching their individual crop requirements. Even with common understanding cropping periods can be staggered so as to minimise the peak requirements. And this can happen only when farmers are made aware of the water schedules much in advance of the sowing season and the soil characteristics and crop behaviour. This needs a very strong extension service.

19. On the basis of climatology, crop and water-holding capacity of soil, the operational plan for the flow is to be worked out keeping in view the actual and realistic system efficiency. This schedule made available to the beneficiaries, much in advance of the season. This would ensure farmers of receiving their allocation in time and provide them time to plan agricultural activities, individually or jointly, by obtaining the advice of experts in agriculture and water management; creating a confidence in the beneficiaries, is required, to accomplish this task. It is essential that there should be a team of officers belonging to different disciplines working together with a monitoring cell; and field staff should provide feed back to the project authorities, whose duty is to be not only evaluating the results of warabandi but also taking effective measures for redressal of shortcomings noticed in the system. The warabandi thus

Contd...7.

presumes the existence of the cooperation between the irrigation officers, agricultural officers and the farmers. The very effective elastic irrigation system from the head to the fields of the farmers guarantees reliable and adequate flow to the field. Adherence to the schedules, fixed for the farmers and maintenance of the entire irrigation system below the pipe outlet will rest with the farmers' organisation. The methodology followed in Pochampad with regard to dividing the Chaks into groups based on geographical position, fixing of flows as per the advice of the Agricultural Department, taking into consideration the area covered the crops grown showed good results. Even in the harvest season and lean season, irrigation waters have been made available to the field of big and small pipe by clubbing the pipes, rotating minors, and even rotating distribution system, with minimum wastage of water.

20. The objective of warabandi is to arrange the distribution of water equitably below the pipe outlet by rotating the turns of farmers and irrigating their fields one after the other. Warabandi system in Sree Ramsagar Project envisages formulation of manageable groups, within such groups, each individual farmer is assured of his share of water at a specific hour of the week, with option to exchange his timings or turn of the week within the group, thus facilitating each member of the group by mutual understanding to adjust the supplies with crop requirements. This flexibility in utilising the water below the pipe outlet helps in mutual understanding and adoption of the cropping pattern of their liking. To select the crop and the quantum of water required, technical guidance is necessary and thus the system needs, not only technically trained persons for running the distribution system, but also for advising the agriculturists to select and irrigate the crop.

21. The success of warabandi thus depends not only on suitable type of irrigation system, but also on an agricultural wing to advise the farmers not only about the crop and its inputs but also about the mutual cooperation among the farmers themselves, and an efficient operational wing to make available needed quantum of water at different stages of the growing crop.

13

EQUITY IN IRRIGATION SYSTEMS - CERTAIN STEPS IN THIS DIRECTION - UKAI-KAKRAPAR COMMAND AREA, GUJARAT

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Our agriculture set up is permeated with inequality. This has been so for decades. Inequality was taken as a fact of life with which we have to live. The land holdings were unevenly distributed; a couple of cultivators had very large holdings, productive power and income. A large number of cultivators worked on very small holdings and supplemented their meagre incomes by working on farms of others. Before independence we had also the system of tenants and landlords; the tenants cultivated the fields at the will of the landlords and the produce belonged to the landlord. The social position w nt to the landholders.

2. We were hirrings against this inequitable system during the independence struggle days. The fact that a few lorded over many in the rural set up went against the very grains of the vast majority of the people. Abolition of tenency and more equitable distribution of land holdings, therefore, formed one of the main items for changing the social order. This became part of the independence struggle.

3. The attainment of independence was soon therefore followed by abolition of tenency. The tenants were made occupants. The majority of the cultivators, therefore, had a state in improving the productivity of the holdings of which they became occupants. Success in plant breeding, evolution of varieties which gave significantly larger yields on application of fertilizers led to increase in agricultural production and improvement in incomes and status of farmers. The increase in income was, however, not evenly distributed. Improved seeds, fertilizers called for larger investments. The credit for financing these investments was more

easily available to the larger holders as compared to the smaller holders. There were also in a position to invest in minor irrigation. The distribution pattern of the benefits which accrued to the cultivators was, therefore, eschewed. The dependence of the marginal farmers and the smaller farmers on the larger cultivators, therefore, increased. They had to depend not only for meeting their credit requirements but also for work during off season on larger land holders. The distribution of credit and inputs was a matter of policy entrusted to the cooperative society. The cooperative societies were suppossed to meet the requirements of the cultivators fully. The policy was further directed towards paying such attention to the needs of weaker sections of the society. The socio-economic order in the villages actually, however, work in a manner that a disproportionately large share of the inputs went to the large land holders. The large land holders were, therefore, in better position to make use of the productive capacity of their land. This was more so in the case of irrigated lands.

4. The 'State' invested large sums in impounding the waters of rivers and provide flow irrigation to a very large areas. It was felt that by constructing a reservoir at suitable place on the river and providing canal waters could be made available to the individual farms and making use of the water so provided production would increase. The production did increase but the accrual of benefits was again aschewed. This was a result both of natural forces acting on the seed as also the incidental effect of the design and implementation of the irrigation system. The information regarding the crop water requirements was rudimentary. It was supposed that particular crops would be grown in certain areas. The forecasting techniques for determining the areas likely to come under individual crops had not been developed. The areas proposed fo individual crops were at best on inspired basis. The sections of the canals were worked out on the basis of crop areas and the crops requirement of water. The canals were designed and constructed

on the principle that it would be able to flow water at a velocity whic would be non-silting and non-scouring. The canal system was designed on the principle that large canals called main canals would take off from the opening in the main reservoir. The release would be controlled by mechanically operated gates. Branch canals would take off at suitable intervals from the main canal. The branch canal would, in turn, be divided into distributaries, minors and sub-minors. There would be gated openings on the minors and sub-minors. The cultivators would combine shaping the land and provide conveyance for taking water from the outlet openings to their individual fields. The outlets were designed to give 70 to 90 litres of water per second. The cultivators ranging from 15 to 40 were supposed to cultivate about 80 ha. of land from this gated opening.

5. The section of the minor could permit flow of only a certain quantity of water. The system was designed to operate for a couple of days followed by flowing of a canal for a number of days and so on. The crop water requirements from the outlet opening is, therefore, to be satisfied within stated period. This pre-suppossed a certain amount of unity and organised working amongst the cultivators. In fact this did not work out in the aforesaid manner. The crops grown were uniform, the crop water requirements differed, the land shaping was not the optimum one conducive to effective use of water. The land shaping itself required availability of trained workers or machines in case of terrain where the slope is in excess of 2%. Water being available only for a fixed duration a certain inequality in its use also developed. Certain cultivators availed of a disproportionate share of flowing waters. What remained was at best of times was not sufficient to enable the weaker farmers to take to crops which depended on flow waters. The result was that large areas remained unirrigated.

6. The conveyance efficiency was also not as high as expected. The leakages and seepages were normally more than that indicated in the design. The improper design of the outlet gates and deficiencies in its operation also led to avoidable unproductive flows

of water. The large length of conveyance system made harmonious working amongst cultivators of effectively utilising it difficult. These shortcomings were noticed and certain remedial actions were taken. See pages, leakages etc. were sought to be reduced by better compaction and lining of the sections of the canals where it was in banking. The outlet sizes were sought to be reduced. The State Government created an organisation for carrying out land shaping and land development using earth-moving machines. Suitable legislation was enacted permitting Government to carry out land development and provide conveyance of water to individual fields. This to certain improvements but we have still a very long way to go in bringing in equity in the use of land and water resources, improving productivity and ensuring socio-economic development. We would illustrate this by taking the developments in Ukai Kakrapar project, a project based upon impounding the waters of river Tapi and using its waters for generating electricity and improving agricultural production in the districts of Bharuch, Surat and Valsad of Gujarat.

7. Ukai-Kakrapar is a two phase major irrigation scheme for development of agricultural lands extending from the Narmada river on the south to the Par river on the south. Although the command area is dissected by eight principal rivers, the main source of supply is the Tapi River. Irrigated agriculture started in 1957-58 when Kakrapar weir was constructed across Tapi river. At that time right bank and left bank canals served an area of 227,540 ha. Since 1972 the 69 m. high Ukai Reservior some 24 km. upstream of Kakrapar weir has povided regulated flows for rabi and hot weather season cropping to an expanded service area now measured 204,080 ha. To serve additional lands lying between the Kim and Narmada rivers, on Ukai Right Bank Canal offtaking from an enlarged Kakrapar Right Bank Canal was constructed. A third canal, Ukai Left Bank Canal, taking off from Ukai dam was added to serve lands lying above the Kakrapar Left Bank Canal.

Project Features:

Ukai Dam: (Construction started 1964)

Masonry	868.8 m
Earthen	4058 m
Maximum height	68.6 m above river bed
Top of Dam	
Crest of spillway	91.135 m
Quantities in dam:	
Earthwork	23.24 MCM
Concrete	0.18 MCM
Masonry	1.304 MCM
Reservoir:	
Gross storage	8511 MCM
Dead storage	1418.49 MCM
Live storage	7092.51 MCM
Full Reservoir level (FRL)	105.156 m.

Kakrapar Weir (construction started 1949)

Crest length	621 m.
Crest elevation	RL155.0 m original RL160.0 m (1971)
Structural height	14 m

Ukai Power Plant

4 units of 75,000 kw each

Irrigation conveyance and distribution system	Length (km)	Bed gradient	Medium capacity (M3/s)
Kakrapar LB Canal	64	1:10000	85.6
Kakrapar RB Canal	64	1:10000	32.5* 78.20
Ukai LB Canal	73	1:8000	35
Ukai RB Canal	48	1:6000	45
Kim Branch KRBC			22.1
Hajira Branch, KRBC			44.77
Surat Branch KLBC			17.16
Chalthan Branch KLBC			20.76
Bardoli Branch KLBC			14.24
Umbhrath Branch, KLBC			12.50
Navsari Branch, KLBC			19.60
Amalsed Branch, KLBC			18.78

Irrigation Service Areas	CCA
Kakrapur LBM Canal	145,335 ha.
Kakrapur RBM Canal	58,745 ha.
Ukai LBM Canal	85,000 ha.
Ukai RBM Canal	67,400 ha.

Present Land Use Pattern (Kakrapar Area)

a) Area under surface irrigation in any one season	124,692 ha.
b) Area under well irrigation	20,000 ha.
c) Orchards	5,305 ha.
d) Cultivable waste	19,850 ha.
e) Current fallow	4,605 ha.
f) Other fallow	6,788 ha.
g) Grass land	10,750 ha.
h) Coastal land	12,000 ha.
	204,080 ha.

Average Irrigation Intensity in Per cent

Year	KRBC	KLBC	URBC	ULBC
1974-75	47.8	47.0	Nil	Nil
1975-76	44.0	45.0	16.7	0.8
1976-77	40.7	43.0	6.6	3.2

8. The climate is predominantly under the influence of the south west monsoon. The 50% probable rainfall for 5 stations in the Left Bank Ukai-Kakrapar scheme area (Surat, Bardoli, Navsari, Chikhli and Valsad) for the 1965 to 1977 period is 1300 mm. July is the heaviest rainfall month with 300 mm in the July 1-15 fortnight and 310 mm in the second fortnight. An averaging of stations has little meaning, however, as rain becomes progressively less from south to north along the Arabian Sea and Gulf of Khambhat. The averaging of stations has little meaning, however, as rain becomes progressively less from south to north along the Arabian Sea and Gulf of Khambhat. The average rainfalls for subareas in Ukai-Kakrapar scheme are as follows :

Name of river Dissecting the Command Area	C.C.A. (Ha.) UKAI	Kakrapar	Total	Average Rainfall (in mm)
Narmada-Kim	62,890	-	62,890	880 - 1150
Kim-Tapi	4,510	61,350	65,860	
Tapi-Mindhola	18,770	76,000	85,770	1450 - 1800
Mindhola-Purna	13,740	28,300	42,040	
Purna-Ambica	10,770	31,000	41,770	1600 - 2200
Ambica-Par	41,720	39,890	81,610	
Total	152,400	227,540@	379,940	

@ C.C.A. under Kakrapar originally estimated at 227,540 ha. on detailed measurements works out to 204,080 ha.

The 50% probable rainfall based on two stations in the RBM Canal area is as follows :

Month	Period	Rainfall in mm
June	11	5
	12	98
July	13	182
	14	111
August	15	69
	16	70
September	17	55
	18	16
		607

9. Surat, an IMD station, is located along the Tapi river between the Left Bank and Right Bank areas. Valsad is an IMD station on the south end of the project near the Par river. Surat's and Valsad's climates are moderated by the influences of the sea. At Valsad the average maximum monthly temperatures vary from 33°C in May, June and October to 28°C in January - a comparatively narrow range. Relative humidity on a monthly average basis varies from 89% to 42%. The corresponding values for Surat are 37° to 24° and 87% to 33% respectively. Mean wind speeds vary from 4 km/hr to 12 km/hr from month to month.

10. The command area slopes gently toward the west and becomes almost completely flat near the coast. In general, the micro-topography is determined by small rivers and natural drainage ways. The need for further land shaping and grading is estimated as follows:

Land slops in percentage	Area needing land development, land shaping and grading in hectares
0.6 to 1.0	7880
1.0 to 2.0	6420
2.0 to 3.0	2850
3.0 to 4.0	450
Total	17600

11. The soils in the command area consist of montmorillonite clays. Though they were initially formed as residual deposits from the disintegration of be salt, they are denuded from the place of their origin, transported by river waters and laid as flood plain deposits. During their transportation they are intermixed with granular material and therefore they very in their texture, stratification and physico-chemical proprties. They are thus alluvial deposits of stratified layers of residual clays intermixed with sands and silts. Because of the presence of montmorillonite clay mineral in appreciable percentage, the soils crack on drying usually to I meter depth and swell on wetting. The cracks are numerous, thin and vertical. On the western side adjoining the coastal area the lands in about 24,000 ha lying in the command area are affected by tidal flow during high tides. The area lying between Ambicaa and Par rivers (82,000 ha) serviced by LKBC and ULBC has a rolling topography and has a large area presently under grass. The rest of the command area under Ukai-Kakrapar is generally brought under more productive crops.

12. The percentage of clay (minus 0.002 mm size varies between 30 and 45 (predominant range). Sand (0.075 to 4.75 mm) and gravel (larger than 4.75 mm) percentage is together usually less than 20. The PH varies between 8.4 and 9.0, indicating a slightly alkaline condition.

13. The land holding classification in the Kakrapar command area is:

Size of holding (ha)	Percentage of farmers having holdings	Percent of area to total area
0-1	39	8
1.0-2.0	21	13
2.0-5.0	27	35
5.0-10.0	10	29
Above 10	3	15
	100	100

14. The development of irrigation on the Left Bank and Right has been bederilled by leakages on aqaduct and difficult shifting soil soils on the Ukai right bank side. We had to go in for constructi-ion of barrels to enable water to pass through the difficult stretch. The irrigation in those areas is now beginning to pick up. The old Kakrapar Project has witnessed a rise in irrigated areas but the constraints of inadequate capacities, rise in water table etc. have limited the growth. The drainage programme has been taken up and the capacities are also being improved. The figures of irrigation for the last 7 years are given in Annexe C-1.

15. The agricultural development was somewhat slower till 1962-63 though irrigation facilities were provided for a large area through Kakrapar system. Intensive agricultural district programmes introduced in 1962-63 in Surat and Valsad demonstrated successfully the potentialities of increasing yields of food crops through a multipronged, concentrated and concentrated and coordinated approach towards application of a package of improved agricultural practices. High yielding varieties were introduced during 1966-67 as a continuation of the programme launched on an All India basis. Arrangements were made for custom hire services for agricultural operations which were further supplemented with processing facilities for agricultural commodities like suger-cane, paddy, cotton, pulses, groundnut and vegetables. Crops

covered under the programme were paddy, wheat, maize, sorghum millets, cotton and castor. To integrate the agriculture operations in the command area and improve infrastructure facilities and organise input and extension services in scientific lines, command area development authority under an Area Development Commissioner was formed in the year 1974 with headquarters at Surat. Since then land development programme got momentum, field channels were constructed over a large area and steps to provide a suitable drainage network were taken by the "Authority". The development of irrigation is presented in the statement at Annex C-2

16. We would further illustrate the attempts made in this direction by describing an experiment which is being carried out in Hanori village of Gandevi taluka of Valsad district. The taluka is bounded by long. between 72.45° to 73.5N and long. between 20° to 21°E. The cultivated area is 280 ha., the population of taluka is 159,000 (as per 1971 census). The village is covered by soils belonging to Jalalpur soil series. Their characteristics are as per Annexe A.

17. We have selected 500 ha. covered by 1L, 2L and 1R sub-minors off-taking from Gadat minor. The Gadat minor in turn takes off from Gandevi distributary. We enclose index plan (Annexe B) showing the position of the Kakrapar Left Bank Canal in Gandavi distributary and the sub-minors selected for experiment. The area within the command of these three sub-minors is 503 ha. The crops grown during the last six years are given in Annexe C. The areas which have been irrigated have been shown in the annexe. It would be seen that a large number of holdings, the cultivators did not or could not make use of the flow irrigation. Certain areas have been devoted the growing of grass and Baval trees. There was considerable disaffection against the system of distribution, water did not reach a large number of fields and whatever of water reached was found to be grossly inadequate. This is in spite of the fact that field channels had been excavated in 1975 at a cost of Rs.66,170/-. We found that there were number of constraints coming in the way of effective use of waters. The

system was not in a position to fully meet the crop water requirements if the entire area be brought under irrigated agriculture. The water supply was irregular. Thecultivators, therefore, were not in a position to risk investments on fertilizer, seeds etc. The yield from the grass and Baval trees was, on the other hand, assured. The existing net-work of farm roads enabling the cultivators to take carts, agricultural implements had been disturbed by construction of canals and field channels. There was no systematic planning for providing an appropriate farm road net-work for taking implements etc. to the individual fields and bringing farm produce from the fields to the village. The soil contains large quantities of clay amounting to 45%. The infiltration rate is 2.5 mm/hrs. The water application for the crop requires 10 hrs/hect. for sugarcane hours. This leaves to the saturation of the soils, upward movement of the salts and reduced nutrient supply to the plants. There is therefore need for providing suitable channels for removing excess waters from the field. The following strategy has, therefore, been adopted. Firstly, the crop water requirement on the supposition that additional areas would be brought under irrigation have been worked out and relevant sections of the Gandavi minor and water course is improved. Additional outlets and control structures have been provided to enable more effective control on the release of waters. These improvements have already been carried out. The section has been improved the linings have been provided in the reaches as shown on the plan. Additional outlets have also been provided as shown on the plan at Annexe B-1. Measuring devices have been provided at Ch.2700' and Ch.5400' of Gadat minor to keep a watch over the flow of water. The difference between two will give an idea of the water used in the fields.

18. The crop water requirements have been worked out on the basis of experiments carried out in the fields of Agriculture College at Navaari. The Agriculture College is part of the Gujarat Agriculture University. We, however, do not have the information on Soil characteristics of individual fields. The information on soils is based on reconnaisance soil survey carried out in year 1970 on a soil characteristics. We have, therefore, decided to test the

computations made on the basis of results obtained from the Navsari fields by actually observing the actual requirements of the individual fields. The crop water computations have been made using the modified penmen formula. The actual time required for individual fields was computed. The time taken to irrigate the field was observed from 12-4-82 to 16-4-82. The two were compared and the results are given in Annexe D. These experiments are proposed to be repeated to enable us to get a better idea of the crop water requirement and effect further improvements in the section.

19. The On-Farm-Development work has also been planned afresh. This incorporates farm roads to individual fields, field channels with lining. To reduce seepage and resulting damage, to the productivity of the soil and better efficiency of the conveyance system. Field drains have also been planned to remove excess water in time. The selected area between Gadat minor and Bokadia khadi is drained out by Bokadia Main drain and Surya Khadi. The section of the drain was originally 1.0 M. average. This has been improved to 1.5 m. The improved section has been worked out on the principle that the precipitation in the catchment is drained out well in time and submergence should be less than 72 hours. This is again on the assumption that the crops tolerance extends to 72 hours. The observation this year revealed that the submergence even after the heavy precipitations has been only 36 hours.

20. The efforts made above have started yielding results even during experimentation stage. The people in this area are used to taking summer paddy. They have been doing so for a number of years. They get very good yields from the summer paddy. Improvement in the system, however, required carrying out works on Gadat minor and sub-minors 1L, 2L and 1R. We tried to do the work making use of the closure available. The minimum period required for taking up the work, however, necessitated closures longer than required for meeting the water requirements of summer paddy. The area under the summer paddy had, therefore, to be reduced. It actually came down from 31 ha. in 1980-81 to about 3 ha. during 1981-82. This sacrifice was made by the cultivators, without demur, willingly. An attempt

has been made to allot time during which cultivators will draw water and irrigate their fields. The time schedules have been arrived at and the definite times affixed. This is to give confidence to the cultivator regarding assured availability of water so as to enable him to plan his agricultural operations well in time. They also put up with the longer intervals in between two waterings.

21. The cultivators have shown willingness to organise themselves, plan and act for better and more equitable distribution of water and increased water efficiency. They have come forward and formed a water cooperative. The water cooperative named "Dhanori Changa Piyat Sahakari Mandli" has been registered. They have by their bye-laws agreed to take water on a volumetric basis and distribute it evenly, equitably and efficiently amongst their members. It is proposed t o charge them 25 Ps. per 10,000 litres from the ensuring season. The State Government, to encourage such cooperatives, provides assistance in the form of trained operators for the first three years as also financial assistance. The projections in respect of expenditure and income of the society is given below at Annexe E. It may be seen that the society would be financially viable with effect from 1985-86. The improvements in productivity, equity and induction of community feeling in the entire village will be the gains. Unity of purpose and cohesive amongst the cultivators is expected to lead to more effective monitoring of the working of the system and timely improvements wherever required. This experiment and those carried out earlier have led to a large demand for formation of the water cooperatives. The State Government has planned to finance twenty water cooperatives this year and the demand as against that already is 37.

Annexe A

JALALPUR SERIES CHARACTERISTICS

Jalalpur series includes moderately drained, deep, clayay soils occuring on nearly level to very gently slopint mid land having 1 to 2% slope with slight to moderate erosion hazard. The principal surface texture is clay, but silty clay and clay loam are also met at places immediately followed by silty clay and clay. The structure is medium to scarse subandular blocky wedge shape peds with shining pressure faces in subsoil horizon. The colour of the soils varies from dark brown, dark grayish brown and very dark brown to dark yellowish brown throughout the profile. Lime concretions, basalt gravels and ferraginous concretions are found. The lime concretions increase alongwith the depth of the profile and at places forming compact pan in substratum. There soils has been classified earlier in India as "Deep black soils". The climate is warm humid to subhumid and air temperature is 23°Cwith mean annual precipitation of 1650 mms. The associated soils are of Sisodra series noncaloarious deep inceptisols.

Jalalpur series comprises member of fine clayay-montmorillonitic, hyperthermic, deep, family or vertic Ustocrets (deep inceptisols).

Typifying pedon : Jalalpur clay cultivated field on 1-5% slope (colour notations are for dry soils unless otherwise noted).

Horizon Depth in cms.	Description
AP 0-17	Dark brown (10 yR 3/3) and very dark grayish brown (10 yR 3/2) clay, coarse columnar subangular blocky structure, very few fine lime concretions (2-5 mm) giving slight localized effevcscegoe with dill Hct dry hard, moist firm, wet sticky and plastic, fine roots plentiful, few small round basalt, neural soil reaction (PK 7.2), diffuse smooth boundry.
B1 17-109	Very dark grayish brown (10 yR 3/2), clay, medium moderate subangular blocky structure with faint shining pressure faces, dry hard, moist firm, wet sticky and plastic, fine roots plentiful, few small round basalt, moral soil reaction (PH 7.2), diffuse smooth boundary.
B2 109-132	Very dark grayish brown (10 yR 3/2) clay, medium moderate angular blocky wedge shape-pads with prominent shining pressure faces, dry hard, moist firm wet sticky and plastic, many irregular lime concretions (2-5 mm) giving strong efferrescance with dil-Hel, few basalt gravels present, diffuses smooth boundary, middly alkaline, soil reaction (PH 7.7).

C.Ca 132-172 Dark yellowish brown (10 yR 3/4) clay, loam, massive in moist condition, while fine subangular blocky in dry condition, dry slightly hard, moist friable, wet slightly sticky and plastic, many impeded lime concretions (2-5 mm) giving violent effervescence with dil-HCL, few basalt gravels (1-2 mm) mildly alkaline soil reaction (PH 7.7).

Range in characteristics :

Solum thickness ranges from 90 to 135 cm. The dominant soil textures are clay, clay loam and silty clay followed by silty clay and clay in B horizon and silty loam, silty clay loam and clay loam are the texture of premeable yellow soils of C horizon. The colour of the soil is dark brown and very dark grayish brown and very dark grayish brown to dark gray in the control section followed by dark yellowish brown in the subsoil. Soil structure is medium moderate subangular blocky peds followed by compact having medium aggular blocky wedge shape faint to prominent shining pressure faces in the subsoil. Lime concretions (2-5 mm) size, white round and irregular few to many are present and increase alongwith the depth and at places in pocket as pan giving strong to violent effevescence with dil-HCL Few basalt gravels are present throughout the profile. The soil vertically cracks deep and wide during dry season. The mean winter and summer soil temperature ranges, from 18°C to 27°C with difference between mean summer and mean winter temperature is 5°C or more. The soil reaction is neutral in the surface soil and gets mildly alkaline in sub-soil.

Competing series

Sisodra soils are clayay having CaC 03 not exceeding 20%

Drainage and Permeability

Moderately drained soils with slow to very slow permeability in wet condition.

Annex C

Statement showing the Seasonwise, Yearwise Irrigation (Dhanori Changa Piyat Sahakari Mandli)

Year	Season-wise figures of Irrigation in Ha.		
	Kharif	Rabi	Hot
1976-77	151	129	112
1977-78	130	104	106
1978-79	142	122	117
1979-80	121	118	113
1980-81	128	108	106
1981-82	132	138	128
1982-83	168	-	-

Annexe -C/2

HOT SEASON 1974-75 to 1978-79

Statement showing the actual irrigation done in Ukai-Kakrapar project from 1974-75 to 1978-79

Season/Name of Crop	1974-75			1975-76			1976-77			1977-78			1978-79		
	Ukai	K'par	Total	Ukai	K'par	Total	Ukai	K'par	Total	Ukai	K'par	Total	Ukai	K'par	Total
HOT															
1. Sugarcane	-	11637	11637	-	10918	10918	47	19382	19429	1084	22426	23510	85	19698	19783
2. Banana	-	1104	1104	-	1564	1564	-	2191	2191	-	2530	2530	2	1768	1770
3. Orchard	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4. Vegetable	-	917	917	-	724	724	-	847	847	-	562	562	-	774	774
5. Paddy	-	-	-	-	-	-	3	-	3	6	-	6	32	-	32
6. Jowar	-	-	-	-	-	-	1	-	1	-	-	-	8	-	8
7. Cotton	-	-	-	-	-	-	1	-	1	-	-	-	1	-	1
8. Groundnut	-	-	-	-	-	-	-	-	-	-	-	-	13	-	13
9. Rajko & other crops	-	-	-	-	-	-	1	-	1	-	-	-	1133	-	1133
10 Other crops	-	8074	8074	-	9586	9586	6	5348	5354	66	5109	5175	258	7478	7736
Total	-	21732	21732	-	22792	22792	59	27768	27827	1156	30627	31783	1532	29718	31250

Annexe D

Operational Schedule of the Outlets/Groups of Outlet of 1L sub-Minor-3rd Irrigation

Sr. No.	Outlet	Design/Actual	Operation timing in Hrs.
1L Sub-Minor	1L-A1 1L-A2 1L-B3	Design/Actual	87/146
	1L-B_2	Design/Actual	54/64
	1L-C_1	Design/Actual	122/237
	1L-D_2	Design/Actual	92/88

(14)

SYNTHESIZING PRODUCTIVE, SOCIAL AND LEGAL RULES FOR EVOLVING AN AGENCY FOR WATER DISTRIBUTION :

1. Er. B. Naik,
Executive Engineer (Agril.)
Command Area Development,
Cuttack, Orissa.

1. Er. S. K. Parija,
Asst. Agril. Engineer,
Cuttack.

1. INSTRODUCTION:

The objective of an irrigation system, constructed and owned by the Government is to help maximising agricultural productivity as well as to equitably distribute its benefits to the society. The Government promises such actions as are consistant with its intentions within the practical limits and expects the society to co-operate so as to enable the Government to realise the planned goal.

Water, which is an input for agricultural production, must be supplied in adequate quantity at the right time at the farm level for enabling the crop to make best use of water. This will not happen automatically. Conscious effort is necessary to achieve this. The job required to do this can be stated as follows.

6 1. Design of the system so as to be able to carry adequate quantity of water to the farm level whenever required.

2. Operation of the system so as to distribute the water as per requirement.

On farm development works, now being carried out in the Command of completed projects ensures the physical requirement as per item one mentioned above.

The objective of this paper is to discuss the problems involved in doing the second job and to suggest the best possible way to organise it. The guiding principles for design of a distribution operation is derived from considering water as a commodity for productive use which

Paper prepared for presentation in the 'Workshop on Productivity and Equity on Irrigation System' from Sept. 21 - 23, 1982 Organised by Giri Institute of development Studies, Lucknow, U. P.

will be scarce unless judiciously used and is likely to be wasted unless carefully conveyed.

2. JOB REQUIREMENT OF WATER DISTRIBUTION.

Water distribution, commonly called "Warabandi" is the most logical and scientific approach for distribution of right quantity of irrigation water at right time to each cropped plot in a Command Area of an outlet. It contains organised instructions for irrigation in the form of a time schedule for each stage of growth involved in the crop production system. Not only it controls use of the precious irrigation water but also it shows clear path for scheduling of other agricultural inputs as crop design in a part and parcel of water scheduling. It focuses on the farmer as the decision maker in the process of agricultural production system and modifies the farmers' attitude, belief, crop knowledge, increases the technical know how and develops a tendency for a co-operative behaviour in him by providing a workable and practical work chart date wise. By doing so, it regulates the interactions of Farmers and his Farming system with the Agricultural Extension, Irrigation and CAD and Revenue systems in such a way that the resultant of the interaction is " Minimum Utilisation of Irrigation water by a farmer for a crop in an unit of land for maximising the productivity". This forms the overall objective of the " Warabandi" system.

From the above definition it is seen that "Warabandi" is not a mere word but it embodies an organised work process which must be carefully analysed before organising the work itself. Since the present analysis is being done for the purpose of suggesting an agency the existing organisations in the State and their job capabilities have to be taken into consideration in order to decide the extent of their participation in the proposed operation.

When one looks at the existing organisations of the Orissa State, four disciplenes are found to be involved in the process of water distribution.They are Agricultural Engineer (C.A.D.), Agricultural Extension, Irrigation Engineering and Revenue Authorities. Further in each disciplene the

Contdp. 3/.

job content are either conceptual, Human or Technical in nature or a suitable combination there of. Accordingly the following job chart (See Annexure- Ia, Ib & Ic) has been prepared based on experience and logical analysis. In addition a rating has been done for the work load falling in each category of job-nature under different disciplenes.

3. TRANSLATION OF THE PRINCIPLES INTO AN AGENCY.

It may be seen from the above analysis that a heirarchy is needed in each of the participating disciplenes for enabling themselves to develop their knowledge and organisation with the development of the concept of "Warabandi". Therefore the concept of a single agency embodying personnel from different disciplenes will fail to fulfil the major part of the objectives.

Alternatively, a plan, that consists of as many vertically parallel agencies as the number of disciplenes involved in the job put parallelly together is adopted. Since the job needs operatives at several levels, even numbers of horizontal tiers are provided in each hierarchy. (See Annex.-II)

The usual difficulty of operating an agency constitued of loosely knitted but relatively independent hierarchies is overcome by assigning the primary role to the one who has the largest job content while others, by administrative arrangement, may be made to participate in the operation by horizontal communication at the correspending level. This cooperation may be poor in the beginning but will develop gradually as the knowledge on the subject grows. The development process will be triggered by the discovery of the reasons of scarcity of water at some of the outlets when scheduling would be attempted.

The graphs shown in 1 to 4 (Annexure -III) will show that the largest job content is for the Agrl. Engineering Organisation. Therefore the primary agency is suggested to consist of an hierarchy of Agril. Engineers. As far as the other agencies are concerned no new personnel are proposed for them because their role actually boils down to provide only information necessary for preparation of the schedule on to do their work better and more expeditiously.

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Since the primary agency will consist of Agril. Engineers the State Government norms for an Engineering hierarchy may be followed to constitute the proposed agency for administrative conveience. The field level staff component shall, however be decided, based on the job requirement. It is proposed as follows:-

There shall be one irrigator, who shall be a part time employee for six months a year, for every 75 Hects. His job shall be to open and close the gates as per the approved schedule and to sense and report any trouble arising in course of the job, to his supervison.

The full time employee at the field level will be designated as ' Warabandi supervisor,' who shall supervise the work of five irrigators or work over 375 Hects.. He shall be the primary agent for field observation, collection of data necessary for preparation of the draft schedule and for its enforcement. On noticing any sort of trouble he shall initiate solution. If the problem as limited to the people of single village he shall convene a meeting of the villagers, if it is concerning neighbouring villages he shall convene a meeting of the representatives of all villages which are served by a single Minor/Water course and shall try to resolve the issue He may invite the canal supervisor to these meetings if he finds it necessary. He shall have a J.E/S.A.E. above him to be supervised by.

One J.E./S.A.E. shall supervise the work of 8 Warabandi supervisors on work for distribution over 3000 Hect. The draft warabandi schedule shall be prepared at his level.

The norms for organisational proportion of an Engineering Division may be followed for deciding the number of Engineering personnel at levels higher than that of the J.E./ S.A.E. The proportion of J.E.: A.A.E. : E.E. in a division is equal to 16 : 4 : 1. Therefore there shall be one maintenance and warabandi division for every 48,000 Hects. This shall be the primary agency to do the job of distribution at the out let level. Such an heirarchy shall cost about Rs. 75/- per Hect. annually.

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4. Operation of the plan of action as per the proposed pattern.

The basic strategy of the operational plan is to distribute the responsibility between the different agencies so as to enable them to look at the problem from different angles, equally spaced from each other to complete an allround vision of the problem. In so doing they will not only complement each others effort but also will see the shortcomings in others as a measure of selfdefense against their ownfailures. The cross-check is expected to help in dispensing the night service to the farmers.

4.1. The Primary agency to plan, obtain approval & operation.

The Agricultural Engineering Organisation which is trained to under stand both the Engineering as well as Agricultural need of farm level Irrigation, shall be primarily responsible for planning and distribution of water at the outlet level. It shall, however be on one hand, supported by the Agricultural Extension agency, for development of a desirable but pra-ctical cropping plan on which the distribution schedule is to be based, and by the Irrigation Department, on ther other for ensuring supply of adequate quantity of water at the head of the Minor/Water course on which the outlets are located. This agency shall get the schedule approved at the appropriate level as per the provisions under the Act after checking up with the farmers.

4.2. Farmers Organisation and its involvement in the process of distribution of water.

The village consolidation committee shall be converted to an irrigation committee or another irrigation committee will be formed who will be the official link between the farmers and the Agricultural Engineering Organisation for the purpose of final acceptance of the schedule. The later, through suitable field staff shall ensure delivery of the planned quantum of water to each farmer, who shall remain present in the field to do the actual irrigation in their respective fields. In cases where action of farmers of one village causes scarcity in another village ; as is the case between two villages

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served by the same minor a form for sitting together with the representatives from each village shall be organised.

4.3. <u>Resolving water disputes & the Mechanism for sensing the reasons thereof & linking with the appropriate agency.</u>

Resolving water disputes, which arises in the field due to various practical reasons is an important part of successful distribution programme. These disputes may be due to impractical cropping plan, incorrect preparation of schedules, non-availability of planned quantity of water at the head of Minor/Water course, damages occuring in supply canals and field channels and last but not the least, due to non co-operative action of one or more undersirable social elements. Resolving these disputes not only has to be done in a legal manner and by appropriate authority constituted for the purpose but also there should be provision for sensing the basic reasons of such disputes so as to prevent their recurrance in future. In addition the reasons for occurance should be suitably linked with the organisations responsible for and capable of preventing recurrance of such difficulties.

5. <u>Social and Legal Implications of distribution of water.</u>

The society, as the user, is constituted of non-coherent elements, each one of whom is self seeking as far as use of water is concerned and therefore unless otherwise controlled, would misappropriate the available water at the cost of others.

On the other hand, the Government as the guardian of the society, promises for equitable distribution of water so as to enable each element to be as highly productive as possible according to a logical plan. Therefore, a code of conduct has been prescribed in the form of Act and Rules to impart legal footing to the provisions to enable the Government to dispense justice in case of disputes between the beneficiaries and control delinquents in the society. This Act along with the rules under it, then becomes the guideline to the operation and therefore the design of any action, or agency must conform to the provisions of the Act.

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The Orissa Irrigation Act 1959 under section 20 provides that " All supply of water from an Irrigation work shall be subject to such rules or orders as may be prescribed or issued by the state Government from time to time with respect to rates, conditions, or any other matter."

The rules of supply under this section have been framed under " The Orissa Irrigation Rules 1961 " which mainly touch the three following aspects, through which the promises and expectations of the state find expression.

(i) The promise for supply of water is mainly related to the base period of staple cereal crop generally grown in the area. A compulsory basic water rate is charged on the area which is certified as culturable and is payable whether this crop is grown or not. Supply to crops in other seasons are subject to sanction of the irrigation Officer, (usually the Tahasildar, who is in-charge of Tax Collection) appointed for the purpose. Additional water tax is payable for that. The staple crop being rice the promise for the major projects is for 28" (70 cms) of supply from June to November.

(ii) The rules also promise for providing scope for adoption of crop patterns, operation of a supply schedule in agreement with the farmers and to ensure supply of the scheduled quantity at the outlet level, but only after such a production programme is applied for by each and every individual farmer and is duely sanctioned. In practice, however, no-body applies, no crop plan is done and approved, no schedule is prepared and operated. Therefore nobody can sue the Government for failure of fulfilment of its promises. The problem continues practically unattended.

(iii) In case of in-sufficient water being available the discretion of altering the scheduled distribution is given to the irrigation officer, subject to any general or special order. There is, however, no orders appear to have been issued yet, dealing it in any special way. The problem appears to have

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been left to the farmers to solve it in any way they can.

6. The Agency responsible for enforcing the Rules and the present situation.

The Agencies for fulfilling this part of the promises on behalf of the Government is the Revenue and Irrigation Departments at the Project level.

It appears that the reason for entrusting this job to Revenue Department is because, apart from collecting taxes, they are supp/osed to deal with the delinquents connected with irrigation offences, which is one of the chief reasons for scarcity in the tailends. Practically, however, the Revenue Department can hardly prove the case against anybody because they never usually get any witness. Nobody comes forward because each of them is a potential delinquent at the time of his need.

The Irrigation Authorities are associated in the job because most of the problems of supply are apparently connected to the repair and release of canal water. But in practice, very little is acomplished in the manner they operate as will be evident from the following facts.

The study presented in Annexure-IV, which was conducted in one of the headend Minors in the Hirakud Command would indicate that the first 50% of the outlets discharge 24.2% more water than they rationally (proportional to the cropped area) require. Most of this extra water flow down the drain un-utilised. Thus it may be concluded that scarcity is not due to shrtage in release of water in to the canal, but it is mostly due to uncontrolled distribution.

As far as people are concerned most of them who have reasons for reacting for non-availability of water are incidentally tax defaulters and said to have been so due to repeated crop failures mainly due to un-expected shortage of water and would prefer to be obliged to Tahasildar for minor reliefs on tax payment or to the irrigation personnel for minor favours for arranging supply at the cost of others rather than for exhibiting unpleasant reaction which does not appear to bear any fruit.

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This arrangement, therefore, has the basic drawback of not being able to bring out the actual difficulty up to the surface and seek solution thereby unduely suppressing a major cause of concern for every body i.e., " Not only a large number of people are discontent against levy of water taxes without water but a major portion of the Command really remains under productive " .

Therefore, it is all the more necessary, that a third organisation must be constituted for sucessful water distribution .

7. The Synthesis .

By now it is apparent that the job of water distribution has primarily three facets-productive, Social, and Legal. Obviously, no one organisation can entirely suit to these needs. Different organisations must exist side by side .

The problem is the one of synthesizing their actions. It is not co-ordination, which we immediately think of as an additional function . It is the one, in which all participating agencies find a means to do their own job better and more effectively by way of imparting more weight to one of their own problem which should be solved to render Warabandi more effective.

This is saught to be done through a series of committees constituted at different levels of operation, These are proposed to be as follows :-

1. Village level Irrigation Committee:-

This committee is to be converted from Consolidation Committee or a new Committee is to be constituted . In case of a village having more than one outlet at least one Member from each outlet shall represent in the committee . The Warabandi Supervisor shall be a member and Convenor of this Committee .

2. Minor Level/Inter village Committee:-

This committee shall be constituted by taking two Members from each village Irrigation Committee from those villages which are served by a single Minor/ Sub-minor . The canal supervisor and the Warabandi Supervisor shall also remain members of this committee . The Warabandi Supervisor shall be the Convenor .

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At upper levels the constitution of committees shall be as follows :-

3. <u>Section level</u> :-

Section Officer (Warabandi)	Member, Convenor .
Irrigation Section Officer.	Member.
Revenue Inspector.	Member.
Agril. Extension Officer.	Member.

4. <u>Sub-Division level</u> :-

Assistant Agricultural Engineer .	Member, Convenor .
Assistant Engineer, Irrigation.	Member.
Tahasildar .	Member.
Additional District Agriculture Officer or District Agriculture Officer.	Member.

5. <u>Division Level</u>.

Executive Engineer (Warabandi)	Member Convenor.
Executive Engineer (Irrigation)	Member.
Deputy Director of Agriculture	Member.
Additional District Magistrate.	Member.

6. <u>Authority Level</u>.

The Governing board shall discuss and resove the issues. However it may appoint a Committee for the purpose.

This meeting will sit one a month during the Warabandi operational period, if needed an emergency seating can be requisitioned by the Executive Engineer (Warabandi).

7. <u>Conclusion</u>.

It is evident from the foregoing discussions that the job of water distribution is a complex but highly evolving job. Many of its intricate problems are suppressed and are not evident at present because there is no agency to take care of it.

Therefore, it is expected, that once an agency is constituted for the purpose, not only it would call for higher level of technical operation but will need a highly

Contd. page-11/-

organised medium to solve the problems.

Therefore, enough room should be provided not only for the needed technological evolution but also for considerable flexibility for reconstrituting the agency and its function as the situation would demand.

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JOB CHART FOR WARABANDI INCLUDING RATING

OUTLET LEVEL

No.	JOB DESCRIPTION		E	A	I	R	T
1	Within an outlet, field-wise analysis of :- Present crops, Yield, Cropping pattern, Soil analysis.	C.	-	-	-	-	-
		H.	-	.50	-	-	.5
		T.	.50	-	-	-	.5
2	Finding information over an outlet with regard to :- C.C.A., Nos and name of farmers, Area Plot wise, Discharge, Distribution system available, Outlet wise maps. Holding size of each farmer.	C.	-	-	-	-	-
		H.	-	-	-	-	-
		T.	.33	-	.33	.33	1.00
3	Data collection and study on physical characteristics of soil i.e. infiltration and percolation rate both in unsaturated and saturated soil conditions.	C.	-	-	-	-	-
		H.	-	-	-	-	-
		T.	1.00	-	-	-	1.00
4	Defining the field water requirements for each class of land and calculation of efficiency factor(Conveyance as well as field application effy.)	C.	-	-	-	-	-
		H.	-	-	-	-	-
		T.	1.00	-	-	-	1.00
5	Design of cropping system and evaluation of water requirement plot wise in a season and there by finding water requirement farmer wise.	C.	-	-	-	-	-
		H.	.25	.25	-	-	.50
		T.	.25	.25	-	-	.50
6	Calculation of irrigation water requirement of all farmers in order to findout the outlet wise requirement.	C.	-	-	-	-	-
		H.	-	-	-	-	-
		T.	1.00	-	-	-	1.00
7	Matching with the available discharge of a sub-minor with the calculated discharge. If it is less than the needed discharge problem is acute.	C.	-	-	-	-	-
		H.	-	-	-	-	-
		T.	1.00	-	-	-	1.00
8	Replanning of the cropping system is done when the available discharge is less than the calculated discharge.	C.	-	-	-	-	-
		H.	.25	.25	-	-	.50
		T.	.25	.25	-	-	.50
9	Judicious cut in discharge in schedule in consultation with farmer(Call for legal consideration.)	C.	.25	-	-	-	.25
		H.	.125	.125	-	-	.25
		T.	.25	.25	-	-	.50
10	Approval of prepared schedule by the appropriate authorities.	C.	-	-	-	-	-
		H.	.50	.50	-	-	1.00
		T.	-	-	-	-	-
11	Operation of schedule. It may be smooth the farmer may not turn up, may go out of schedule. Each is a problem to be solved.	C.	-	-	-	-	-
		H.	.33	.33	-	-	.66
		T.	.33	-	-	-	.33
12	Discharge in the outlet falling short of requirements due to offence committed in the upstream (below the head of minor). Seek technical social or legal solution.	C.	-	-	-	-	-
		H.	.17	-	.17	.17	.50
		T.	.17	-	.17	.17	.50
13	When scarcity of water is due to reasons caused above the minor head works the hierarchy is triggered.	C.	.06	.08	.08	.08	.33
		H.	.08	.08	.08	.08	.33
		T.	.08	.08	.08	.08	.33
14	Making suggestions for improvement.	C.	.50	-	-	-	.50
		H.	.50	-	-	-	.50
		T.	-	-	-	-	-

Legend-:

C - Conceptual.
H - Human.
T - Technical.

E - Agril. Engineering.
A - Agril. Extension.
I - Irrigation
R - Revenue.
T - Total.

ANNEX-Ib

JOB CHART FOR WARABNDI INCLUDING RATING

CANAL LEVEL

No.	JOB DESCRIPTION.		E	A	I	R	T
1	Discharge of minor, subminor and distributary.	C.	-	-	-	-	-
		H.	-	-	-	-	-
		T.	.50	.50	-	-	1.00
2	Matching the calculated water requirement of all outlets with the design discharge. If it is less than the needed discharge problem is acute.	C.	-	-	-	-	-
		H.	-	-	-	-	-
		T.	1.00	-	-	-	1.00
3	If calculated discharge is less than the designed discharge, the contact should be made with irrigation department.	C.	-	-	-	-	-
		H.	.25	-	-	-	.25
		T.	.50	-	.25	-	.75
4	Technical scrutiny on the scheduling chart.	C.	-	-	-	-	-
		H.	-	-	-	-	-
		T.	1.00	-	-	-	1.00
5	Coordinating the extension system, village irrigation committees, irrigation authorities.	C.	-	-	-	-	-
		H.	1.00	-	-	-	1.00
		T.	-	-	-	-	-
6	Planning new system in scheduling, trial of new technology in water distribution system.	C.	-	.50	-	-	.50
		H.	-	-	-	-	-
		T.	.50	-	-	-	.50
7	Introduction of new cropping system.	C.	.25	.25	-	-	.50
		H.	.25	.25	-	-	.50
		T.	-	-	-	-	-
8	Supervision of the different operation being carried out at the field level.	C.	-	-	-	-	-
		H.	.50	.50	-	-	1.00
		T.	-	-	-	-	-

COMMAND LEVEL

No.	JOB DESCRIPTION.		E	A	I	R	T
1	Policy formulation in distribution system finding availability of water in the system and the total need.	C.	.13	.13	.13	.13	.50
		H.	.13	.13	.13	.13	.50
		T.	-	-	-	-	-
2	Matching total calculated water requirements with available discharge at Main Head works and needful accordingly.	C.	-	-	-	-	-
		H.	-	-	-	-	-
		T.	.50	-	.50	-	1.00
3	Planning cropping system to be followed.	C.	-	-	-	-	-
		H.	.50	.50	-	-	1.00
		T.	-	-	-	-	-
4	Establing high degree of Coordination from village level irrigation Committees to State level authorities.	C.	-	-	-	-	-
		H.	.25	.25	.25	.25	1.00
		T.	-	-	-	-	-
5	Establing training system Research studies etc.	C.	.66	-	-	-	.66
		H.	.33	-	-	-	.33
		T.	-	-	-	-	-
6	Introducing the technological changes (example- present system of open lined channel may be replaced by pipe irrigation system etc.	C.	.66	-	-	-	.66
		H.	-	-	-	-	-
		T.	.33	-	-	-	.33

Legend:-

C - Conceptual.
H - Human.
T - Technical.

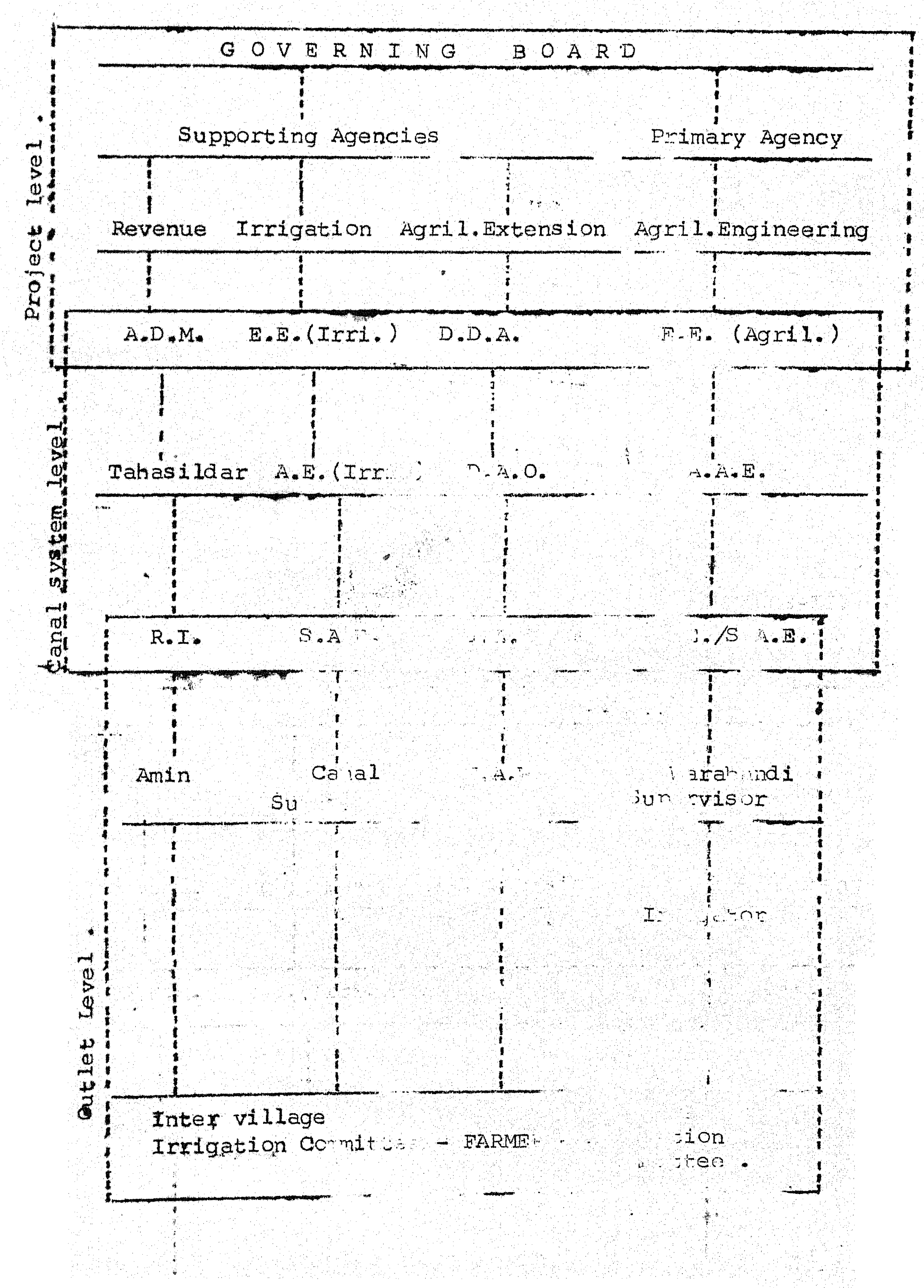
E - Agril. Engineering.
A - Agril. Extension.
I - Irrigation.
R - Revenue.
T - Total.

Annex-Ic

CUMULATIVE JOB CONTENT

Description of levels.	Content of job nature in different disciplenes in percent.												Cumulative in percent.		
	Agril.Engineering			Agril.Extension.			Irrigation			Revenue					
	C	H	T	C	H	T	C	H	T	C	H	T	C	H	T
Outlet level	6.18	21.12	49.70	.59	3.35	6.18	.59	1.86	4.32	.59	1.86	4.32	5.95	36.85	57.21
Canal system level.	9.37	25.00	43.75	3.13	9.38	-	-	-	9.38	-	-	-	12.50	34.38	53.13
Total Command Area level.	2219	20.16	13.83	2.16	14.66	-	2.16	6.33	8.33	2.16	6.33	-	30.50	47.33	22.16

ORGANISATION CHART. ANNEXURE-II.



ANNEX-III

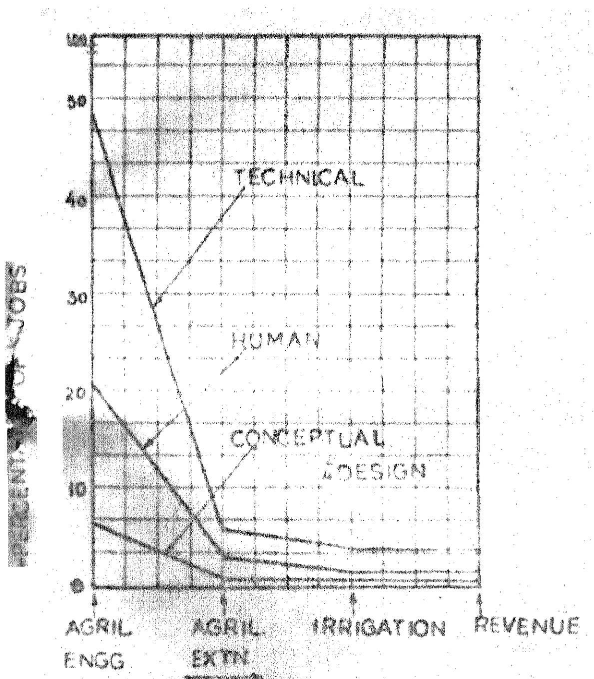


FIG 1 OUTLET LEVEL

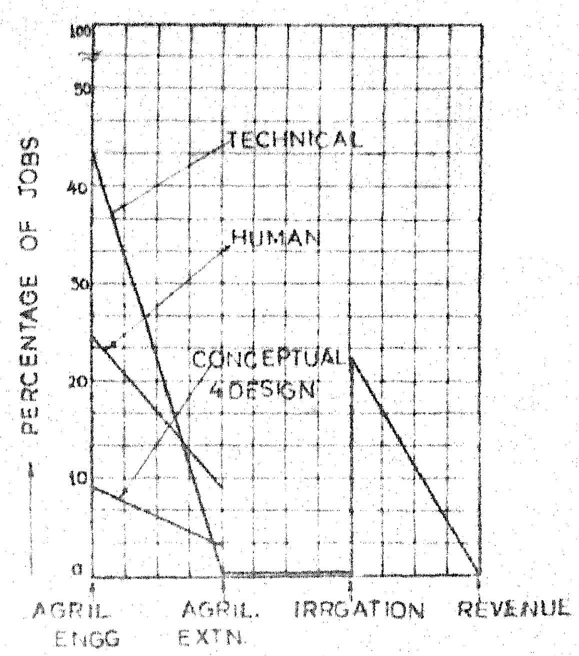


FIG 2 CANAL SYSTEM LEVEL

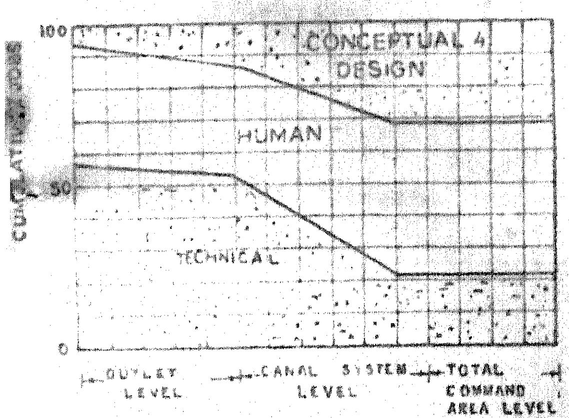


FIG. DIFFERENT TYPES OF KNOWLEDGE FOR THREE LEVELS WARABANDI SYSTEM

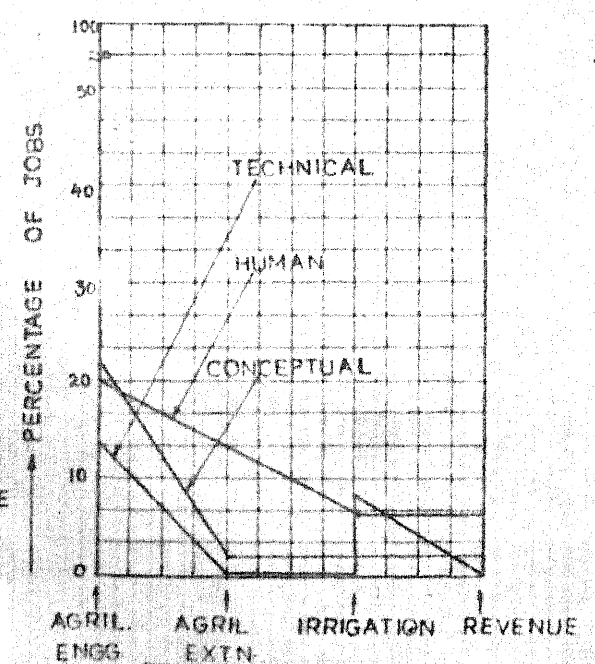


FIG 3 TOTAL COMMAND AREA SYSTEM

Statement showing actual and Rational pattern on the basic of actual average duty.

Annex-IV

Village boundary along the supply canal.	Actual discharge in cusec.	Rational discharge based on cropped area actual duty in cused	% difference between actual supply and rational supply.	% of supplied water lost to drain, as furface flow.
1	2	3	4	5
Balbaspur	1.39	0.94	+ 47.87	30.21
Talab	9.78	9.12	+ 7.23	29.00
Madhupur	2.29	0.65	+252.30	50.00
Talab	1.54	0.66	+133.33	7.00
Bhalukenda	0.71	0.92	- 22.82	19.00
Talab	0.56	0.80	- 32.50	[illegible].00
Barmunda	0.48	1.19	- 59.66	33.00
Debeipali	0.32	1.00	- 68.00	10.00
Majhipali	0.16	0.62	- 74.19	0.00
Total:-	17.23	15.9[illegible]	[illegible].36 %	28 %